KANT'S COSMOGONY

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KANT'S COSMOGONY

AS IN HIS ESSAY ON THE RETARDATION OF THE ROTATION OF THE EARTH AND HIS NATURAL HISTORY AND THEORY OF THE HEAVENS

WITH INTRODUCTION, APPENDICES, AND A PORTRAIT OF
THOMAS WRIGHT OF DURHAM

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"To suppose a reader thoroughly indifferent to Kant, is to suppose him thoroughly unintellectual."—DE QUINCEY.

"Great as the currency of his leading ideas has been, much still remains in his works to be developed by the struggle and collision of future systems; and it may be safely pronounced that no philosopher of the eighteenth century, perhaps none since the days of Aristotle, has left behind such monuments of thought, or has so firmly imposed the task of mastering them on the speculation of all succeeding ages."—JOHN CAIRNS.

To

THE RIGHT HON.

LORD KELVIN, G.C.V.O.

EMERITUS PROFESSOR OF NATURAL PHILOSOPHY IN THE UNIVERSITY OF GLASGOW

THIS BOOK IS DEDICATED IN VIEW OF HIS HIGH APPRECIATION OF KANT'S SCIENTIFIC WORK AND HIS OWN GREAT ACHIEVEMENTS IN NATURAL PHILOSOPHY

'Suum cuique.'

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TRANSLATOR'S INTRODUCTION.

KANT'S Cosmogony never stood so high in the estimation of the scientific world as it does to-day. The history of this original and profound speculation of the young Königsberg thinker on the constitution and formation of the physical universe has something strangely interesting and romantic about it, and may even be regarded as one of 'the fairy tales' of modern science. His *Natural History and Theory of the Heavens*, as he ultimately designated its exposition, will probably be regarded hereafter as the most wonderful and enduring product of his genius. It left the press—for we can hardly say it was *published*—in 1755, when Kant was in his thirty-first year; and it bears upon it everywhere the impress of that youthful ardour and unrivalled daring of thought which, in its own sphere, at once outstripped Newton, while most faithful to him, and more than anticipated Laplace in outlining the true Nebular Theory of the origin of the universe. But Kant's immortal work, so pregnant with the spirit of discovery and modern scientific thought, fell, as David Hume said of his own first Treatise, 'still-born from the press'; and it was not till nearly a century afterwards that its great merit and significance began to be recognised by the leaders of science. That recognition has been growing in depth and volume during the past fifty years, and it is no exaggeration to say that Kant's speculation now holds the foremost place, in its essential positions, among all the scientific cosmogonies of the time. No knowledge of physical astronomy is now complete without reference to it.

I. Relation of Kant's Science to his Philosophy.

The view thus indicated may, nay, must, appear surprising, and even untenable at first sight, to those who know Kant only as the founder of the Critical Philosophy and the creator of the speculative spirit of the great German systems of thought. But none the less true is it, when critically and historically viewed, in the light of the final issues of these philosophical systems. The *Critique of Pure Reason*, even with the addition of the two great supplementary Critiques, has worked itself out to a certain hopeless result which has almost been fatal to the progress of philosophy itself, through the brilliant idealistic movement from Fichte to Hegel, till the cry in the philosophical schools for a time has been 'back again to Kant,' as the still unexhausted explorer of pure reason, and the fresh inspirer of new philosophic effort. But while the Neo-Kantian school, which rules so largely the thought and method of the hour even in the sphere of science, has repudiated Hegel, as Kant in his last days so emphatically repudiated Fichte, it has not risen above the detailed investigation of Kant's scientific phenomenalism ; nor has it been able to secure the ground of real objective knowledge of the universe, which was the chief object of his search, or to transcend his critically elaborated Agnosticism. In this comparative helplessness and inefficiency of the Neo-Kantian philosophy, with all its admitted loyalty to the great master so far as it goes, a new position has been coming ever more clearly into view, even on the philosophical standpoint. For, under the predominating scientific influence of the time, philosophy has been becoming more and more *scientific;* and in its demand for real scientific truth, as the material of rational elaboration, it is being driven back from the Kant of the great 'Critique' of 1781 to the earlier Kant of the Newtonian natural philosophy. In other words, the philosophical watchword of the realistic spirit of the time must be enlarged and defined anew, so as to embrace a return to Kant in his primary scientific work, and to his original scientific creation.

To the purely philosophical student of Kant this position may appear to be inconsistent with Kant's own development, or even to be refuted by it. But such a view only arises from a certain onesidedness in the prevailing philosophical interpretations of Kant. Kant did indeed put forth the *Critique of Pure Reason* as the exposition of a revolution in thought. He was roused from his 'dogmatic slumber,' as he tells us, by the scepticism of David Hume; and with intense consciousness of the issue at stake he proceeds, somewhat laboriously and ostentatiously, to discuss the problems of philosophy from a new point of view. This came as a surprise to his age; and the persistency, elevation, and earnestness with which he carried out his discussion, gradually won for him the supreme position in the European philosophy of the eighteenth century. It has been generally at this point that philosophical students have begun and carried on their study of his system, without reference to what preceded and underlay it. His earlier scientific work, like an inner planet merged in light, was thus almost entirely lost sight of in the blaze of his later philosophical splendour. And even the greatest of his followers, originators of new speculative schools as they were, never got truly behind his distinctively philosophical period; and none of them rivalled or even approached him in genuine scientific capacity and achievement. Fichte was too deeply absorbed in subjective thought and its independent creativeness, to care for Kant's careful physical investigations. Schelling, with all his poetic sympathy with Nature and his vital touch, had neither the scientific method nor the exact mathematical training which Kant brought to its interpretation. And even Hegel, with all his marvellous constructive power and comprehensiveness in thought-forms of his own, and with all his resolute pursuit of objective knowledge that should be at once philosophical and scientific, took up Kant chiefly, if not solely, on his formal ideal side, and was still too much swayed by Fichte and Schelling and the spell of the Greek metaphysics, to give more than a new dialectical elaboration of Kant's speculative system and of the idealised world of history, in which he moved as a master. The truest scientific follower of Kant in the philosophic schools was Herbart, in his own chair at Königsberg, who likewise drank deeply of the fresh invigorating stream of the Newtonian philosophy, and who brought to bear upon the problems of thought a mathematical facility and a devotion to exact science, kindred to that of Kant himself. As Aristotle said of Anaxagoras, Herbart, amid the idealistic intoxication of the time, with his severe sobriety of thought and self-limitation to the world of reality, seems now to be 'as one sober among the drunken.' But Herbart has hardly yet been seriously studied in England, except by the representatives of the new psychology which he originated, and the educationists who have found their best guidance in his suggestive methods. Krause excelled all the other great epigons of Kant in the precision of his higher psychological analysis, and the incisiveness of his renewed criticism of Pure Reason, whereby he rationally escaped from the Agnosticism of Kant, and opened the inner life of his pure receptive soul for the whole play of the divine idea of the world. But his comprehensive ideal realism was also a child of the time, and shrank with ideal sensitiveness from the firm grasp of the primitive movement of matter as we find it in the strong Hercules grip displayed at the outset by Kant.[1] Along with many translations, we have very able philosophical interpretations of Kant; but most of these deal with the Critical Philosophy from the Hegelian standpoint, and can hardly be said to reproduce the purely scientific spirit of Kant's own thought, or to render it in its completeness. They shed much valuable reflected light upon Hegel as regards the origin and meaning of his Dialectic; but they have little or nothing to say of Kant's incomparably greater merit as a scientific discoverer and a true scientist.

Kant himself had no unscientific limitations. His thought, while ever striving to be universal, was scientific, or at least aimed to be scientific, all through. Even in the vortex of his later philosophical speculation, he did not forget his scientific vocation, nor did he cease to prosecute it. The

[1] I have lately published *The Ideal of Humanity and Universal Federation*, by K. C. F. Krause (T. & T. Clark, Edinburgh), which may be regarded as a popular introduction to Krause's system of thought.

motto prefixed to the *Critique of Pure Reason* is taken from Bacon. In undertaking it he compares himself to Copernicus as referring the world of thought to a new centre. The very first problem he raises in the *Critique* and deals with as cardinal to the whole question of the origin and limits of human knowledge, is that of the nature of mathematical science and its fundamental generating intuitions, Space and Time. His criticism of the operations of the understanding is all directed towards re-establishing the validity of the idea of physical causation, and the reliability of empirical knowledge and natural science in opposition to the scepticism of Hume. And when he comes to deal with Pure Reason itself, in its highest struggles and efforts to reach super-sensible knowledge of the world, of the spiritual being of man, and of God, he clips the wings of all airy speculation in this sphere, by uncompromising reference to the world of sensible reality; and he tries to demonstrate the impossibility of speculative knowledge of these supreme non-sensible objects, just by showing that the methods and laws which are valid for empirical science cannot be scientifically applied to them. He is thus scientific all through, according to the conception of science worked out in the Baconian school; and the results of his earliest and latest speculations, notwithstanding their apparent contradiction, are, when rightly interpreted, in entire harmony with each other. Kant has been called 'a

Prussian Hume'; I would rather call him a Prussian Comte, with less interest no doubt than Comte in the mere formal interrelations of the sciences, but with a far deeper insight into moral and religious truth, and a much more fertile elaboration of the possibilities of individual thought. And Kant, without any sense of self-contradiction, has put beyond question this view of his consistent interest to the last in physical science, as the chief work of man's logical thought, by his never ceasing to lecture in his peculiarly attractive way on the details of Physical Geography and Anthropology, by his pausing in the prosecution of his critical philosophy to systematise the principles of Natural Science in 1786, by his virtually indicating the great discovery of Thermodynamics four years after he wrote the *Critique of Pure Reason*, and by dealing with the influence of the moon on the weather so late as 1794. We must take Kant in his entirety if we are to understand him rightly in *any* relation, and not interpret him from a mere corner of his system as a philosopher, or by dealing with one only of his many suggestive ideas.

As I have said elsewhere: 'Kant undoubtedly owed much to the fact that he was a thorough scientist before he became a speculative metaphysician. His own development was typical of the revolution of thought which has produced modern philosophy: that certain knowledge of the real world must be the basis of all true knowledge of the ideal world, or that

Physics must precede Metaphysics. He happily began his work by appropriating all the mathematical and physical science of his age, and he made it the stable foundation and criterion of all his subsequent thinking. He was a faithful disciple of Newton, to whose principles and method he owed most of his formative power. . . . He laid it down that "the genuine method of Metaphysics is one and the same in principle with that which Newton introduced into physical science," and he never lost sight of this criterion and point of view. In the possession so far of certain knowledge, he thinks as a metaphysician and physicist, all through his criticism of the pure Reason, from beginning to end, and from his primary certainty to his final result.' [1]

II. The Scientific Return to Kant.

It is to the leaders of physical science in the nineteenth century, and not to the speculative philosophers, that we owe the true appreciation of Kant's scientific work, and the disclosure of its rare and abiding value. The two complete editions of Kant's works—that of Hartenstein of 1838-39, and that of Rosenkranz and Schubert of 1838-42—brought the material of Kant's scientific writings, in connection with the revival of direct study of Kant, to the hand of all his students. But the interest

[1] In my introduction to Kant's *Principles of Politics* (T. & T. Clark), where I deal more fully with the scientific character and habit of Kant's thought through the whole three periods of his development.

in Kant was still mainly philosophical even in Germany, and it was predominantly Hegelian, as we see in Rosenkranz, who gave but a meagre account of Kant's scientific work in his otherwise excellent sketch of Kant's system of Philosophy. Even Schubert, who edited the scientific writings, includes the Cosmogony in vol. vi., under the general rubric of 'Physical Geography' (!), with a still very imperfect appreciation of the value of Kant's scientific work in detail. But the scientists proper now took up Kant, with adequate knowledge, from their own point of view. The distinguished French astronomer, M. Arago, in 1842, first called the attention of scientists to Kant, whom he calls 'the Astronomer of Königsberg,' and declared that his name in that connection did not deserve the oblivion into which it had fallen, while he was quite astonished at the inexplicable silence of Herschel regarding him.[1] In 1845, Alexander von Humboldt, who may have directed the attention of Arago to Kant when studying at Paris, in the first volume of the *Kosmos* recognises the place occupied by Kant along with Wright, Lambert, and Sir William Herschel; refers to him as 'the great philosopher' who had so admirably investigated the earthquake of Lisbon; and afterwards designated him as 'one of the greatest spirits of the eighteenth century,' and 'the immortal philosopher of Königsberg.'[2] Two

[1] *Annuaire pour l'an* 1842, 2nd edition, Paris.

[2] *Kosmos*, I. 90; I. 217; III. 558.

years later, in 1847, Struve, the distinguished astronomer of St. Petersburg, expressed himself in a highly laudatory manner concerning the 'sublime enterprise,' exhibited in Kant's Cosmogony.[1] Schopenhauer, who made an independent philosophical return to Kant, and who shared largely in the scientific spirit, pointed out emphatically the priority of Kant to Laplace in the exposition of the Nebular hypothesis.[2] Helmholtz, with still greater scientific authority, in a discourse delivered at Königsberg in 1854, put the same view prominently before the public;[3] and in a later popular lecture on the 'Origin of the Planetary System,'[4] delivered at Heidelberg and Cologne in 1871, he puts the relative merits of Kant and Laplace in the clearest light. But of all the German scientists, Zöllner—a typical and somewhat one-sided German of the new school in his physical speculation and criticism—did most to establish Kant's absolute originality in works published in 1865 and 1872, and to vindicate Kant's claims to the first place of honour in connection with the Nebular theory.[5] Dr. Reuschle, in 1868, summed up lucidly Kant's whole work and merit in the sphere

[1] *Etudes d'Astronomie stellaire sur la voie lactée et sur la distance des étoiles fixes.* St. Petersburg, 1847.

[2] *Parerga und Paralipomena*, II. 143.

[3] *Ueber die Wechselwirkung der Naturkräfte und die darauf bezüglichen neuesten Ermittelungen der Physik.* Königsberg, 1854.

[4] Translated in Helmholtz's *Popular Lectures on Scientific Subjects*, by Professor E. Atkinson. Second Series. 1881.

[5] In his *Photometrische Untersuchungen*, Leipzig, 1865, and his *Ueber die Natur der Cometen*, 1872.

of Natural Science.[1] Ueberweg in 1865, and Hay in 1866, dealt specially with the Cosmogony, and Liebmann, in 1874, continued the comparison of Kant and Laplace. Dr. Konrad Dieterich in 1876, in his *Kant and Newton*, gave an admirable sketch of Kant's scientific relation to Newton, illustrating it by apt quotations from his scientific writings.[2] In 1875, Fritz Schultze, in his work entitled *Kant and Darwin*, excerpted the leading passages of Kant's Cosmogony and other writings in connection with the doctrine of evolution;[3] and in 1880, Dr. Karl du Prel, criticising the 'Kant-Laplace theory,' also finds it completed by Darwin.[4] A popular edition of the *Natural History and Theory of the Heavens*, carefully edited by Kehrbach, was introduced into the German 'Universal Library';[5] and another excellent edition for students of science has been edited with notes by A. J. von Oettingen in Ostwald's 'Classics of the Exact Sciences.'[6] Knowledge of the interest and importance of Kant's Cosmogony thus became diffused through the scientific atmosphere of Germany, and rapidly spread wherever German science was studied. The German historians of philosophy followed the lead of the

[1] In his article in the *Deutsche Vierteljahrs-Schrift*, 31 Jahrg., 2 Heft., 1868, entitled: 'Kant und die Naturwissenschaft.'

[2] *Kant und Newton*. Tübingen, 1876.

[3] *Kant und Darwin. Ein Beitrag zur Geschichte der Entwicklungslehre*. June, 1875.

[4] *Die Planetenbewohner und die Nebularhypothese*. Leipzig, 1880.

[5] *Universal-Bibliothek*, 1954, 1955. Good Bibliography and references.

[6] Ostwald's *Klassiker der exacten Wissenschaften*, Nr. 12, 1898.

scientists, and gave a more prominent place to Kant's scientific work. Ueberweg clearly saw its importance, and outlined it with his usual literary accuracy; and Kuno Fischer gives a comparatively full and attractive summary of it in his brilliant exposition of Kant's philosophy.

Of late years the respective merits of Kant and Laplace in connection with the Nebular theory, have become almost a subject of international controversy between the German and the French scientists, and they have respectively found eager and even impassioned advocates on either side of the Rhine.

In 1880, A. Meydenbauer attempted to show up 'the contradictions of Laplace's theory with facts and rational principles,' and to press the issue of the alternative, 'Kant *or* Laplace,'[1] entirely in favour of the former. On the other hand, M. Wolf, Astronomer of the Paris Observatory and Member of the Institute, published in 1886 his valuable work on the *Cosmogonic Hypotheses*, in which he attempts to dispose of the accumulating objections to Laplace's theory, defends it while sharply criticising Kant's views, and, although rejecting them, he completes his work with a French translation of Kant.[2] M.

[1] *Kant oder Laplace. Kosmologische Studie*, von A. Meydenbauer. Marburg, 1880. Meydenbauer is unfavourably criticised by A. J. v. Oettingen, *l.c.* p. 151.

[2] *Les Hypothèses Cosmogoniques : Examen des Théories Scientifiques Modernes sur l'Origine des Mondes, suivi de la Traduction de la Théorie du Ciel de Kant*, par C. Wolf, Membre de l'Institut, Astronome de l'Observatoire. Paris, 1886.

Faye, in his learned and original work on the *Origin of the World*, gives an excellent historical account of the Cosmogonic theories of the Ancients and the Moderns, and dedicated the work, in its third edition of 1896, to the memory of Arago, who had introduced him to his astronomical career in 1842. With exemplary impartiality, M. Faye endeavours to give both Kant and Laplace their due, but his criticism leads him from both to the endeavour to elaborate a new modified theory of his own.[1]

Kant's relations and merits as a scientist have a peculiar interest for English students of the subject, but knowledge of them was slow to come in England. Whewell, in his *History of the Inductive Sciences*, published in 1837, makes no reference to Kant's scientific work, and can hardly be supposed to have known it, although he mentions his name once in connection with his view of the 'Moral Argument.'[2] Sir John Leslie, in his *Dissertation on the Progress of Mathematical and Physical Science, chiefly during the Eighteenth Century*, contributed to the seventh edition of the *Encyclopædia Britannica* in 1842, in like manner does not mention Kant, nor Thomas Wright of Durham, although he refers to Lambert; and in the same volume Dugald Stewart, perplexed and irritated by the growing popularity of Kant's

[1] *Sur l'Origine du Monde. Théories Cosmogoniques des Anciens et des Modernes*, par H. Faye, de l'Institut. 3. éd. Paris, 1896.

[2] Vol. 3, 469.

philosophy, which he could not understand, still tries to show that 'his claims to originality were ill-founded,' and he declaims at large on the 'evil which has arisen from his writings.' It was really Professor De Morgan's *Account of the Speculations of Thomas Wright of Durham* in 1848 (reprinted below in Appendix C) which first drew the attention of English scientists to Kant's scientific work; and it is evident that De Morgan, stimulated by the reference of Arago, owed his information about Kant not to direct study of his writings, but to the competent guidance of Struve. In the admirable article on Kant by Dr. Cairns in the eighth edition of the *Encyclopædia Britannica* in 1857, Kant's *Theory of the Heavens* is appreciatively mentioned and its style commended, but its full significance is not yet grasped. Robert Grant, in his able *History of Physical Astronomy* (1852), makes but the briefest reference to Kant (p. 574); and even such an excellent work as Professor Nichol's *Cyclopædia of the Physical Sciences*, while giving a brilliant exposition of the nebular theory of Laplace, has nothing to say of Kant. Herbert Spencer, in his *First Principles*, published in 1862, makes no mention of the greatest modern expounder of the theory of cosmic evolution; and while in expounding his own theory and law of evolution he embraces the sidereal heavens within its range, he has yet in view only Laplace's hypothesis, and still continues to accept generally the Ring theory.[1] To Professor Huxley the merit must be assigned of being the first English scientist who clearly understood and adequately appreciated Kant's Cosmogony as in the original German; but he still writes of it as 'seemingly little known.' In his *Essay on Geological Reform*, published in 1869, he writes: 'The sort of geological speculation to which I am now referring (geological aetiology, in short) was created as a science by that famous philosopher, Immanuel Kant, when, in 1775 [1755], he wrote his *General Natural History and Theory of the Celestial Bodies; or, an Attempt to Account for the Constitutional and Mechanical Origin of the Universe, upon Newtonian Principles.* In this very remarkable but seemingly little known treatise, Kant expounds a complete Cosmogony in the shape of a Theory of the Causes which have led to a development of the universe from different atoms of matter, endowed with simple attractive and repulsive forces.'[2] A still greater master of physics, Lord Kelvin, shortly afterwards declared that Kant's treatise only wanted the knowledge of thermodynamics 'to lead to a thoroughly definite explanation of all that is known regarding the present actions and temperatures of the sun.'[3] Lord Kelvin and Professor Tait, hand

[1] 'The substance of every planet in passing through its stages of nebulous ring, gaseous spheroid,' etc. 5th ed., p. 318 (1887).

[2] Huxley's *Collected Essays*, Vol. VIII., p. 320-1.

[3] Address to Geol. Society, Glasgow, April 5, 1869.

in hand with Helmholtz, have given their adhesion generally to the principles of Kant's Cosmogony; and their supreme authority in this country may now be quoted as not only approving it, but as working out its results, with all the available resources of contemporary mathematical and physical science. The Meteoric theory, which has been rapidly supplanting the Ring hypothesis of Laplace, and which is being worked out with special devotion by our English scientists, is practically only the development and empirical verification of Kant's theory. The Dynamical theory of Heat is already found potentially in Kant, even in reference to the heat of the sun; and the extraordinary progress that has been made in recent years, by means of spectrum analysis and other finer methods of astronomical observation, all tend to give further confirmation to Kant's views in detail. Lord Kelvin thus sums up the position of the Meteoric theory: 'The form of Meteoric theory which now seems most probable, and which was first discussed on true Thermodynamic principles by Helmholtz, consists in supposing the sun and his heat to have originated in a coalition of smaller bodies, falling together by mutual gravitation, and generating as they must do according to the great law demonstrated by Joule, an exact equivalent of heat for the motion lost in collision.'[1] Again, recently, he founds

[1] Thomson and Tait: *Treatise on Natural Philosophy*, New ed. I., 493.

upon 'the almost certain truth that the earth was built up of meteorites falling together.'[1] This is just Kant developed and translated into the scientific language of to-day. Zöllner sneers approvingly at Professor Tait for saying that, 'even among our greatest men of science in this country there is comparatively little knowledge of what has been already achieved, except, of course, in the one or more special departments cultivated by each individual'; and he adds that, 'this single proposition characterises more than all else the present state of science in England.'[2] But this reflection never applied to Professor Tait himself, nor to Lord Kelvin, and, thanks largely to their noble work and examples, it is now rapidly becoming inapplicable even generally. As regards Kant in particular, his early scientific work has already become part of the current material of the popular scientific writer. The late Mr. R. A. Proctor did a good deal on this line, in his astronomical writings, to popularise the name of Kant as a scientist, but in 1874 he still says, 'if the name of Kant is held in high honour, how little is this due to its association with astronomical theories!'[3] Dr. Chapman, in his

[1] *The Age of the Earth.* By the Right Hon. Lord Kelvin, G.C.V.O. Being the Annual Address for 1897 of the Victoria Institute.

[2] *Ueber die Natur der Cometen*, Vorrede, XL., LVI.

[3] *The Universe and the Coming Transits*, 1874. But Mr. Proctor can hardly have read Kant for himself, as he shews only superficial and incomplete knowledge of Kant's views. As will afterwards be seen, there are essential errors in the following statement: 'Kant's speculations, so far as they relate to the present constitution of the universe, must be regarded as simply an extension of Wright's theories. Kant

Pre-Organic Evolution,[1] and other theological writers on the vexed question of Evolution and Teleology, likewise recognise the merit of Kant's early physical speculation. Professor Oliver Lodge, in his *Pioneers of Science*, 1893, refers to Kant as the real originator of the 'Nebular Hypothesis,' but his interest is mainly confined to Laplace. And above all, Mr. Gore, in his attractive work on the *Visible Universe*, of the same year,[2] draws a good account of Kant from M. Wolf, and gives him at last his due place in English, as M. Wolf had done in French, in the very front of the modern scientific cosmogonists. The most recent historians of astronomy among us, such as Miss Agnes M. Clerke (1885), and Mr. Arthur Berry (1893), have introduced Kant's work, with correct recognition of its detail and importance, into their historical surveys. In America, where the progress of German science has of late been carefully followed and studied, Kant's work is now well known. It may be enough to refer here to Professor Newcomb's summary of the 'Ideas of Kant,' in his *Popular Astronomy*, 1878, and to the able article, with competent criticism, on 'Kant as a Natural

had read Wright's work, the *Theory of the Universe*, which had been reprinted in a Hamburg journal of the year 1751,' *l.c.* p. 178. Had Mr. Proctor known Kant better he would have taken a firmer attitude towards Laplace, and even found abundant support in him for some of his own speculations.

[1] T. & T. Clark, Edinburgh, 1891.

[2] *The Visible Universe*, chapters on the Origin and Construction of the Heavens. By L. Ellard Gore, F.R.A.S., 1893.

Philosopher,' by Geo. F. Becker, in the *American Journal of Science*, Vol. v., February, 1898, to which my attention has been called by Lord Kelvin, and which shows clear and complete knowledge of the subject, founded on direct study of Kant's works. Mr. Becker sums up his excellent review thus: 'In his preface to his theory of the heavens, Kant says: "I seek to evolve the present state of the universe from the simplest condition of nature by means of mechanical laws alone." After more than one hundred years of rapid progress in science, it cannot be denied that his attempt was astonishingly successful.'

This may suffice here, without adding further detail, to establish the statement with which we started, that 'Kant's Cosmogony never stood so high in the estimation of the scientific world as it does to-day.'[1]

[1] Our most distinguished recent philosophical expounders of Kant have also referred to Kant's early scientific work; *e.g.* Dr. Edward Caird, 'The Critical Philosophy of Immanuel Kant' (*Early Essays on Physics*, Vol. I., p. 103), 1889; Dr. Hutchison Stirling, Art. 'Kant' in *Chambers' Encyclopædia*, New Edition, 1890; and Dr. Adamson, Art. 'Kant' in the *Encyclopædia Britannica*, 9th Edition, 1881. Dr. Adamson, with keen discernment of the scientific trend of all Kant's thought, says, relevantly and well, that Kant 'combined in a quite unusual degree knowledge of physical science with speculative acuteness and devotion to philosophy. No other thinker of modern times has been throughout his work so penetrated with the conceptions of physical science; no other has been able to hold with such firmness the balance between empirical and speculative ideas.'

III. Kant's Scientific Environment and Antecedents.

When, on the line of the scientific Return to Kant, we reach his own scientific environment and antecedents, we see at once how directly these conditioned his own scientific achievements. Kant stands in certain respects midway between Newton and Laplace, and he is the most original German link between the two great English and French scientists. He was born in 1724, three years before Newton's death, when the *Principia* was just beginning to captivate the great mathematicians on the Continent, and he lived to see the publication of the *Exposition du Système du Monde* in 1796, and the first three volumes of the *Mécanique Céleste*; but by that time his mental powers had begun to decay, and his work was done. He received his chief impulse to the study of mathematical and physical science in the University of Königsberg, from the teaching of Martin Knutzen, one of the earliest avowed Newtonians in Germany, a man of great promise who died comparatively young, but who led Kant, while a student, to the independent study of the *Principia*, and to the enthusiastic appropriation of Newton's Natural Philosophy.[1] Kant

[1] Borowski, our best authority, says: 'Kant came to the University of Königsberg in 1740. Martin Knutzen, who had become very famous by several writings well received in his time, was the teacher to whom Kant chiefly attached himself at the beginning of his

showed a mathematical precocity and a daring in mathematics somewhat akin to that of Newton himself, and in his twenty-second year he published his first mathematical work entitled, *Thoughts on the True Estimation of Living Forces* (1746-7),[1] in which he already ventured to cope with Descartes, Leibnitz, and Euler; and if, as mathematicians now hold, he did not successfully solve their standing controversy upon the question, and even fell into considerable errors, he yet exhibited a new and profounder grasp of the problem. As this work has not been translated, nor is likely to be translated, Ueberweg's account of it may be here reproduced, with his comments in brackets:

academic career. He attended uninterruptedly his instruction in Philosophy and Mathematics. He also heard the lectures of R. Teske, a learned and very upright man. When Kant afterwards graduated as master, giving in an Essay on Elasticity to the Philosophical Faculty, Teske gave this creditable testimony to it, that he had himself learned much from this "specimen."—But this Knutzen took the highest place among all his teachers. Knutzen traced out for him and others the path upon which they might become not mere imitators, but, some day, independent thinkers. It was unfortunate that this Knutzen, from the injustice of fate, did not find a happier lot in his country. He died in 1756, as Professor Extraordinarius of Philosophy, universally honoured and beloved by the great circle of his students, who, like Kant, owed to him the greatest part of their philosophical and mathematical knowledge. . . . . In April, 1756, after Knutzen's death, he sought to obtain in his place the position of Professor Extraordinarius, but without success.' (He did not obtain that position till 1770.)—*Darstellung des Lebens und Characters Immanuel Kant's, von Kant selbst genau revidirt und berichtigt.* 1804.

[1] *Gedanken von der wahren Schätzung der lebendigen Kräfte u. Beurtheilung der Beweise, deren sich Leibnitz u. Andere Mechaniker in dieser Streitsache bedient haben.*

'The question, whether the force of a body in motion is to be measured, with Leibnitz and others, by the product of the mass, and the square of the velocity (mv^2), or with Descartes, Euler, and others, by the product of the mass, and the simple velocity (mv), is here termed by Kant—the source of one of the greatest schisms existing among the geometricians of Europe; and he expresses the hope that he may be able to contribute to its composition. He advances against the Leibnitzian view, then prevalent in Germany, several objections which tend in favour of the Cartesian, but admits, nevertheless, the former with a certain limitation. Kant divides all motions into two classes; the one class including motions supposed to persist in the body to which they are communicated, and to continue *in infinitum*, unless opposed by some obstacle; the other consisting of motions which cease, though opposed by nothing, as soon as the external force by which they were produced ceases to operate. (This "division" . . . is completely erroneous.) Kant affirms that the Leibnitzian principle applies to the former class, and the Cartesian to the latter. If the conception of force be regarded, as is now customary, as merely an accessory conception, the controversy itself can no longer exist, since then only the determination of what are the phenomena of motion and their laws is directly of objective importance, while the definition of force becomes a question of methodical convenience. If by force is meant a cause proportionate to the quantity of the motion of a body, the Cartesian principle, of course, applies; but if the power of the body in motion to produce certain special effects, *e.g.*, to overcome a continuous and uniform resistance, is what is meant by force, the Leibnitzian formula is applicable, according to which, the "work" performed by the "force" is equal to the difference of the products of half the mass multiplied by the squares of the velocity at the commencement, and at the end of the motion. (At the present time, as is known, mv is used to designate the "quantity of motion," and mv^2 "the living force." In the case of a body falling freely, the final velocity after n seconds $= 2ng$, and the distance traversed in n seconds $= n^2g$. One half of the product of the mass by the square of the velocity =

$$\tfrac{1}{2}mv^2 = \tfrac{1}{2}m \,.\, 4n^2g^2 = 2mn^2g^2 = 2gm \,.\, n^2g,$$

or the product of the "moving force" ($2gm$) by the distance (n^2g). The heights to which bodies rise when thrown upwards vary, therefore, as the squares of their initial velocities; and in like manner, generally, the "work" performed by a moving body is measured by half the product of the mass into the square of the velocity.) D'Alembert showed as early as 1743, that analytical mechanics can leave the disputed question on one side, since it is only a dispute about words. From the present standpoint of science, B. W. H. Lexis, in an inaugural dissertation (Bonn 1859), expresses the following judgment: "Kantius, gravidis quidem erroribus laborans, tamen multis locis profundiorem rei ostendit perspicientiam." Yet at the bottom of the discussions lay concealed by the contest of words the problem, how to combine the principle of the equality of cause and effect with facts. A characteristic affirmation is made by Kant in § 19, that metaphysics, like many other sciences, had only reached the threshold of well-grounded knowledge.'—*History of Philosophy*, Vol. II., p. 142.

When Kant published his first work, he had left the University, and he was engaged thereafter as a private tutor for about ten years, till he completed his Cosmogony in 1754-5. In the winter session of 1755, he qualified as a lecturer in the University of Königsberg, and thus entered on his great public career as the first teacher and thinker of Germany. He confesses naïvely that he was not a success as a tutor, and it may have been because his intellectual energy, during that quiet period of deepening and ripening thought, was so much absorbed in working out his Cosmogony. The scientific conditions of the time were most favourable to the stimulation of original thinking upon this ultimate and most difficult problem of physical science. The great Continental mathematicians were all gradually being won from Descartes and Leibnitz to the Newtonian Philosophy, like the open-minded but yet obscure Königsberg student; and the Academies of Science at Paris, St. Petersburg, and Berlin, with a noble rivalry, competed for the honour of connecting the greatest names with their work. Frederick the Great, stimulated by his French models, and impelled by the happy conviction that the political development could only prosper if it went hand in hand with the new movements of science, divided the energy of his active mind between the promotion of scientific work in Prussia and the political complications which were bringing him anxiously to the verge of the Seven Years' War. He had succeeded in persuading Euler to leave St. Petersburg and come to Berlin in 1741, to reorganise his Academy of Sciences; and when the great mathematician returned to St. Petersburg, on a pressing invitation from the Empress Catherine II. in 1756—blind in one eye and the light fast fading in the other—his special work at Berlin was accomplished. Frederick similarly tried to draw D'Alembert from Paris to Berlin, as Catherine II. tried to allure him to Russia; but although the great French mathematician and academician met the philosophical king ('Philosophe Roi') in Holland, he preferred his simple independence in gay Paris to the proffered honours at sombre Berlin. Frederick's ambition was, however, gratified in 1766, when, at the suggestion of D'Alembert, he asked Lagrange to succeed Euler as the head of the mathematical section of the Berlin Academy, giving as a reason that the greatest king in Europe wished to have the greatest mathematician in Europe at his Court; and there he retained him for 21 years. M. de Maupertuis, a pronounced Newtonian (1698-1759), won from the flattery of Paris by the more seductive offers of Frederick, after he had established a reputation by his Lapland expedition and the measurement of a northern arc of nearly one degree, was installed as Perpetual President of the Berlin Academy, 1st February, 1746, and he administered the office, 'in red wig with yellow bottom,' as Carlyle describes him, to Frederick's entire satisfaction till his death, on 27th July, 1759.[1] Through the king's lavish flattery, on the one hand, and the administrative ability of Maupertuis on the other, the Berlin Academy of

[1] See Carlyle's vivid sketch in his *Frederick the Great*, IV. 9.

Sciences thus became the chief focus of Continental science, at the very time when Kant was silently prosecuting his 'voyage of discovery' through the infinity of space and time. It soon eclipsed all the other Continental Academies and even Newton's Royal Society, in the abundance and fertility of its work; and it either drew the great mathematicians in person to its halls, or attracted their best contributions to the pages of its *Transactions*, which were printed mostly in Latin or French, to the close of the century. The busy brain of Euler contributed 60 papers in all on important topics in mathematics and physics from the beginning of 1744 till the beginning of 1755, and other 61 by 1778. The younger Euler began to move in his footsteps in 1754. Maupertuis contributed 10 papers from 1746 to 1756. Lambert contributed 51 papers from 1761 to 1784. Lalande sent 3 papers in 1750. Daniel Bernoulli contributed 5 papers from 1745 to 1765; and John Bernoulli followed in his train with 52 papers from 1756. Lagrange contributed 63 papers in all from 1765 to 1803.[1] Between the work of its Ordinary and Foreign Members, the Berlin Academy thus exercised an immense influence in stimulating and directing the scientific spirit in Prussia about the middle of the eighteenth century. The great problems then under discussion by these master minds

[1] For the subjects, see the *Verzeichniss der Abhandlungen der Königlich Preussischen Academie der Wissenschaften, von* 1710-1870.

of the time, were mainly those problems of Mathematical Dynamics and Gravitational Astronomy which had been left uncompleted, or unsolved, by the supreme genius of Newton; and they one and all applied themselves to their solution with the greatest devotion, perseverance, and enthusiasm. In particular, the problems arising out of the applications of Newton's Law of Gravitation to the motions of the Planets and their satellites in the solar system, called forth and exercised all their powers. Newton had mathematically established the law of Gravitation as holding between any two bodies, such as the Earth and the Moon, and the Sun and each of the Planets, but it still remained to verify and apply it to the disturbances or perturbations observed in the motions of the several members of the Planetary System, arising from the effect of their mutual attractions upon each other. Newton's final problem was, therefore, this: 'Given the eighteen bodies,' then known as making up the solar system, 'and their positions and motions at *any* time, to deduce from their mutual gravitation, by a process of mathematical calculation, their positions and motions at any other time; and to show that these agree with those actually observed.'[1] But the problem in this universal form could not then be solved exactly

[1] *A Short History of Astronomy*, by Arthur Berry, p. 288, 1898. Sir John Leslie gives a good account of this problem and its discussion in his *Dissertation*.

by the available mathematics; and so it took the more particular form 'of the so-called problem of the three bodies, viz., given at any time the positions and motions of three mutually attracting bodies, to determine their positions and motions at any other time.' Even this problem could not be satisfactorily solved by the mathematical methods of that time, and only approximate solutions by the methods of the higher analysis could be reached.[1] The whole of the elaborated detail of these formal mathematical investigations of the eighteenth century was completed and summed up by Laplace in his immortal work, the *Mécanique Céleste*, the first of the five volumes of which appeared in 1799, and in which the stability of the solar system and the permanent periodicity of its perturbations were only too dogmatically demonstrated. About 1750 these mathematical researches were largely directed to the problems arising out of the motions of the Moon, and the consequent construction of Lunar Tables, which were desiderated at the time as of the greatest practical importance both for observational Astronomy and Navigation. In 1713 the British Government had offered a reward of £20,000 for the discovery of a method of finding the longitude at sea to within half a

[1] See, *e.g.*, Euler's Papers, *Considérations sur le problème des trois corps*, 1763, and his *Nouvelle Méthode de déterminer les dérangements dans les mouvemens des corps célestes, causés par leur action mutuelle.* 1763.

degree, and the great mathematicians eagerly worked at the task. Euler published his Lunar Theory (*Theoria Motuum Lunae*) in 1753; Clairaut and D'Alembert also took up the question; and Tobias Mayer calculated Tables of the Moon, which were transmitted to England, and which were so favourably judged by Bradley that his widow received £3000 on account of them in 1765. Clairaut also published a set of tables of remarkable accuracy; and the Berlin Academy, keeping watch over all these mathematical efforts, published an annual almanack embodying the latest results, which became so popular that it was for a time the chief source of the revenue of the Academy.

But the Lunar theory was still complicated with various difficulties, which were considered from every possible point of view in connection with the relations of the three bodies—the Sun, the Earth, and the Moon. In particular, certain inequalities in the Moon's motion established then by observation, brought great confusion and uncertainty into the mathematical calculations. In the seventeenth century Halley had already practically established what is called 'the secular acceleration of the moon's mean motion,' and it ever more urgently demanded investigation and explanation of its cause. It was at this point that a new question was raised in the Berlin Academy, and set as the subject of a public prize essay for 1754; and it was in connection with the subject of this prize essay that Kant made known his first great discovery in Physical Astronomy, namely, the Retardation of the Rotation of the Earth by the action of the Tides.

IV. Kant's Discovery of the Retardation of the Rotation of the Earth.

The subject propounded by the Berlin Academy for the Prize Essay of 1754 was this: '*Whether the Earth in its Rotation round its Axis, by which it brings about the alternation of day and night, has undergone any alteration since the first period of its origin. What may be the cause of this, and what can make us certain of it?*' The *Transactions* of the Academy give us no light on this subject. They furnish no hint as to how the question arose; nor as to whether any competitive essays were sent in, or any decision given. Indeed, they contain no reference to the subject at all. All our information concerning it is derived from Kant alone. He was just then engaged in working out his Cosmogony and writing his *Natural History and Theory of the Heavens*, and when he came to the point at which this question was relevant to his speculation, he passes it by with a reference to the problem set by the Royal Academy of Science, reserving his solution on that account meanwhile (see *infra* pp. 107-8). It may be that Kant's mind had been working on this very subject, or that the statement of the problem had also suggested to him his solution, which probably came to him in a quick flash of thought, as has been so often the case with men of genius when they suddenly grasped a new discovery. Kant may have even intended to submit an essay in competition, and it is sometimes stated that he did this; but assuredly he did not do it. Although his solution was most clear and certain to his own mind, he could not work it out with the fulness of demonstration which he considered was necessary to satisfy the conditions of the problem. He could find no *historical* evidence of any alteration in the period of the daily rotation of the earth; but he recognised, apparently for the first time, a *physical cause* constantly in action, which must bring about a certain retardation of the earth's rotation round its axis. This cause he discerned in the action of the Tides as, moving from east to west, they constantly break upon the surface of the earth in its opposing and resisting movement from west to east. This was Kant's original discovery of the effect of tidal friction in retarding the earth's rotation. He did not send in a competitive essay, but he published his solution, so far as worked out, in a weekly Königsberg journal, entitled the *Wöchentliche Frag- und Anzeigungs-Nachrichten* (a sort of 'Weekly Notes and Queries'), in which scientific contributions of the kind occasionally appeared. Kant's paper appeared in Nos. 23 and 24, *i.e.*, about the middle of June, 1754.

We owe the preservation of this interesting paper to Borowski, an intimate friend of Kant in his later years, who mentions it as No. 2 of Kant's writings in his *Sketch of the Life and Character of Immanuel Kant, exactly revised and corrected by Kant himself*, 1804, already referred to. The statement of Borowski was no doubt derived from Kant himself, to whom it was submitted for his verification in 1792, although it was not published till after Kant's death, in 1804. So far as I know, this important paper is not referred to elsewhere in Kant's own writings. It was first republished by Nicolovius in 1807;[1] and there it rested till it was reproduced in the collected editions of Kant's works (Rosenkranz, Bd. vi., 1839; Hartenstein, 1838-1839 and 1867-1868; as also in Von Kirchmann's edition in 1873). Hartenstein has collated the later text with the original in the Königsberg journal, so that we are sure we now have it exactly in the terms in which it was written.

A translation of this interesting paper is here presented for the first time in English, and as it reproduces the comparatively brief original very literally, it need not be analysed; but a few points of special interest in connection with it may be merely pointed out.

(1) It is evident that Kant's paper must have been written very rapidly. A slip in the text which has

[1] *Sammlung einiger bisher unbekannten gebliebenen kleinen Schriften I. Kant's.* Königsberg, bei Fr. Nicolovius, 1807.

escaped all the editors, and which can only be accounted for by the hurry of the composition, of itself proves this (see p. 9 n.). Moreover, the result of Kant's calculation of the amount of the consequent retardation is very vaguely reached, and is much too large. The probability is that Kant delayed the statement of his solution until the time for the publication of the decision of the Academy's prize had almost arrived, and that he hurriedly wrote this paper, and published it at once in the Königsberg journal lest he should be forestalled by some of the essayists. A remarkable parallel to this in the present century, in the publication of what is commonly regarded as the greatest scientific discovery in the evolutionism of the nineteenth century, will occur to every one, although this generally believed parallel has been denied.

(2) Kant was therefore keenly alive to the novelty and importance of his solution, but he did not introduce it into the greater work on which he was engaged. He seems to have regarded it as not so satisfactorily worked out in detail, as to justify the introduction of it. He was apparently satisfied with the publication of his idea in the journal, so that he could point to it and claim it at any time; and although he did not so claim it publicly at any time, as we have seen, he did not forget it. At the same time, he used it as the medium through which he announced the forthcoming publication of his Cosmogony, with an indication of

its contents (see last sentence of the paper, *infra*, pp. 10, 11).

(3) Lord Kelvin has rightly pointed out that no previous mathematician or physical astronomer had discovered or anticipated Kant's solution—and with this Professor Tait and M. Wolf agree; so that it appears to be absolutely original.[1] But it is relevant to raise the question, which very naturally occurs, as to how, and on whose suggestion, the Berlin Academy came to propose this problem at that time? In the absence of direct evidence, we can only proceed by inference, and it appears to me that it was Euler who most probably raised the question in this form, although Maupertuis may have actually so formulated it. We find a hint of this in a much later work of Kant, in his *Lectures on Physical Geography*, published by Rink in 1802-3, but containing matter which had gathered in Kant's hands through many years. In the Second Supplement to this work, printed from Kant's own MS., he mentions that Euler had advanced the theory of the gradual shortening of the course of the year, and in a letter to the Danish Bishop Pontoppidan (1698-1764) (who was made Bishop of Bergen in 1747, and Vice-Chancellor of the University of Copenhagen in 1755), he had expressed the hypothesis that the daily rotation of the earth had perhaps been gradually shortened from causes unknown, whereby the differ-

[1] Lord Kelvin, *The Age of the Earth*, p. 7; Tait, *Recent Advances of Physical Science*, p. 8; Wolf, *Hypothèses*, p. 173 n.

ence in the period of revolution must have become imperceptible.[1] Of course, Kant knew nothing of this hypothesis in 1754; but it is relevant here as showing what had been passing in Euler's mind. Confirmation of this view is also found by reference to the nature of the subjects then being dealt with by Euler in some of his papers to the Berlin Academy.

(4) Very remarkable is it that Kant seems to have abandoned his early theory altogether, and that he worked out later exactly the opposite view in support of Euler's conjecture. The said Supplement II., to his *Physical Geography*, is entitled 'Of the *Acceleration* of the daily rotation of the earth'; and accepting this idea, on Euler's authority, he founds it upon the view, then becoming prevalent, that the central mass of the earth was in a molten or fluid state, so that the heavier particles were continually falling towards the centre, carrying with them a greater velocity of rotation than the lighter particles which might be ascending from the centre, and which would tend to a certain internal relative retardation. He also suggested the increasing *contraction of the mass of the earth* as a cause of its increasing rotational speed, yet he does not confidently assert or found upon it. But Kant in this late 'Note' holds quite clearly to the former cause, and consequently to the view of the continual acceleration of the rotation.[2] Kant's later

[1] *Kant's Werke*, R. VI., 786.

[2] Lord Kelvin, as is well known, has pointed out that the increase of the mass of the earth by meteoritic deposit will cause retardation, but this did not occur to Kant.

view, however, even if it had been well founded, would not entirely or necessarily disprove his earlier solution; it would only complicate the calculation of the amount of the tidal retardation. But Kant does not recur to his former view, nor even mention it. Euler's theory, however, falls with the abandonment of the old hypothesis of the molten state of the internal mass of the earth, and the acceptance of the new view of its practically perfect rigidity as maintained by Lord Kelvin.[1] Kant's original discovery thus remains unaffected, and is now almost universally accepted.[2]

(5) The most important application which Kant made of his great discovery was to the explanation of the past retardation of the rotation of the Moon round its axis, until it has come to correspond to its monthly period of revolution around the Earth, and to the anticipation of the retardation of the rotation of the Earth, until it shall come to be equal to the monthly revolution of the Moon around it. The Earth will then turn always the same face to the Moon, just as the Moon now does to the Earth, and the Moon shall then appear to it as standing always on the same meridian, on account of the

[1] W. Thomson (Lord Kelvin) 'On the Rigidity of the Earth' in the *Transactions of Roy. Soc.*, May, 1863; and *Treatise on Natural Philosophy*, I., 422.

[2] But v. Kirchmann, strangely, still opposes Kant's view on the ground that the tidal wave is only a vertical rising and falling of the water of the ocean (*Erläuterungen*, Phil. Bib., 63). Surely he can never have seen a tide breaking on a shore.

equalisation of their rotations. According to Kant's calculation, there would be required 27½ million years before this condition would be reached. All this is to be found explicitly in Kant, although it is commonly supposed that it is all matter of much later discovery, and it furnishes very striking evidence of the original and logical character of his genius. Even the recognition of the great retarding tides that swept round the Moon, in the train of the Earth's attraction upon its primitive fluid state, stands quite clearly before us already in Kant's early discovery.

The later history of this peculiarly interesting question is well known; it is to be found indicated in all our best text-books, and even in popular writings on the subject. Laplace put forth another, but more hypothetical solution of the question in 1789, founded upon a characteristic theory of the variation of the form of the Earth's orbit within certain definite limits. In 1824 he gives the same view as Kant had done. The distinguished German physicist, J. R. Mayer of Heilbronn, again professes to give as original the same solution of the question,[1] and in almost the same terms, as Kant; and the Kant solution of 1754 is compared in parallel columns with the Mayer solution of 1848 by Zöllner, with an almost cruel conscientiousness.[2] On 11th December, 1865, the French academician, M. Delaunay, submitted a Treatise to the French

[1] *Dynamik des Himmels*, 1848. [2] *Natur der Cometen*, p. 472.

Academy, 'on the existence of a new cause, having a sensible influence on the value of the secular equation of the Moon,'[1] propounding practically Kant's solution again. Adopting Delaunay's suggestion as true, Adams, in conjunction with Professor Tait and Lord Kelvin, calculated the diminution of the Earth's rotatory speed with incomparably greater accuracy than ever before, but still on the basis of Kant's original idea. Lord Kelvin has done much by his important relevant discussions to promote the elucidation and extension of Kant's point of view, as in his discussion of the 'Thermodynamic Acceleration' of the rotation of the Earth (*Transactions Roy. Soc. of Edinburgh*, 1881-2, p. 396); and he informs us that his brother, the late Professor James Thomson, of the University of Glasgow, independently grasped the discovery in 1840, and discussed it in conversation. The late Dr. Croll also treated the subject with his well-known acuteness and ingenuity. The very remarkable mathematical and physical speculations of Professor H. G. Darwin on the action of Tidal Friction and the formation and movements of the Moon, have given a new interest to the subject, and bring it up to date.[2] And now we begin to pluck the ripe fruit of Kant's seminal idea.

[1] 'Sur l'existence d'une cause nouvelle ayant une influence sensible sur la valeur de l'équation seculaire de la Lune.'—*Comptes rendus*, T. 61, p. 1023.

[2] *The Tides*, 1898, the Art. 'Tides' in the *Encyc. Brit.*, 9 ed., and the celebrated Papers in the *Philosophical Transactions*, 1879-1881.

Thus did Kant's 'really great discovery'—as Lord Kelvin calls it—advance on its way, 'per varios casus, per tot discrimina rerum,' until it has now become all but universally accepted by contemporary scientists. *Palmam qui meruit, ferat!*

1. Lord Kelvin's Statement of Kant's Discovery.

We may here quote Lord Kelvin's most recent statement (1897) concerning Kant's discovery. 'Kant pointed out in the middle of last century, what had not previously been discovered by mathematicians or physical astronomers, that the frictional resistance against tidal currents on the earth's surface must cause a diminution of the earth's rotational speed. This really great discovery in Natural Philosophy seems to have attracted very little attention,—indeed to have passed quite unnoticed,—among mathematicians, and astronomers, and naturalists, until about 1840, when the doctrine of energy began to be taken to heart. In 1866, Delaunay suggested that tidal retardation of the earth's rotation was probably the cause of an outstanding acceleration of the moon's mean motion reckoned according to the earth's rotation as a timekeeper found by Adams in 1853 by correcting a calculation of Laplace which had seemed to prove the earth's rotational speed to be uniform. Adopting Delaunay's suggestion as true, Adams, in conjunction with Professor Tait and myself, estimated the diminution of the earth's rotational speed to be such that the earth as a time-keeper, in the course of a century, would get 22 seconds behind a thoroughly perfect watch or clock rated to agree with it at the beginning of the century. According to this rate of retardation the earth, 7,200 million years ago, would have been rotating twice as fast as now: and the centrifugal force in the equatorial regions would have been four times as great as its present amount, which is $\frac{1}{289}$ of gravity. At present the radius of the equatorial sea-level exceeds the polar semi-diameter by $21\frac{1}{2}$ kilometres, which is, as nearly as the most careful calculations in the theory of the earth's figure can tell us, just what the excess of equatorial radius of the surface of the sea all round would be if the whole material of the earth were at present liquid and in equilibrium under the influence of gravity and centrifugal force with the present rotational speed, and $\frac{1}{4}$ of what it would be if the rotational speed were twice as great. Hence, if the rotational speed had been twice as great as its present amount when consolidation from approximately the figure of fluid equilibrium took place, and if the solid earth, remaining absolutely rigid, had been gradually slowed down in the course of millions of years to its present speed of rotation, the water would have settled into two circular oceans round the two poles: and the equator, dry all round, would be 64·5 kilometres above the level of the polar sea bottoms. This is on the supposition of absolute rigidity of the earth after primitive consolidation. There would, in reality, have been some degree of yielding to the gravitational tendency to level the great gentle slope up from each pole to equator. But if the earth, at the time of primitive consolidation, had been rotating twice as fast as at present, or even 20 per cent. faster than at present, traces of its present figure must have been left in a great preponderance of land, and probably no sea at all, in the equatorial regions. Taking into account all uncertainties, whether in respect to Adams' estimate of the rate of frictional retardation of the earth's rotatory speed, or to the conditions as to rigidity of the earth once consolidated, we may safely conclude that the earth was certainly not solid 5,000 million years ago, and was probably not solid 1,000 million years ago.'—*The Age of the Earth*, 1897, p. 7; cf. *Nat. Phil.*, § 830 (1883).

2. Dr. Reuschle on Kant's Mathematical Calculation.

It has been already remarked that Kant's calculation of the rate and amount of the Retardation of the rotation of the Earth by the action of Tidal Friction is much too great. We may here quote in illustration what Dr. Reuschle says on this point, which he has carefully considered, his Footnotes being put in brackets. 'Kant even seeks by an approximate calculation to estimate *the amount of the retardation*, which he finds to be for every second equal to the weight of a body of water of 237½ million cubic feet, and which is exceeded by the volume of the Earth "123 billion times." He reasons from this to the time in which the whole axial rotation of the Earth would be "exhausted" —as he peculiarly expresses it—by the resistance; and by this he means the time in which the retardation would amount to as much as the time of rotation itself had been at the beginning of the period, *i.e.*, one day—with which, however, the axial rotation itself is by no means "exhausted," as Kant comes afterwards to say towards the end of his discussion. He finds two million years; *i.e.*, after the close of that time one rotation of the Earth would last two of our present days, and a year would contain only half as many rotations, or days, as at present, and from this there follows for a period of two thousand years, an increase of the day by 86 seconds. (Or as Kant expresses it; after 2,000 years, the year will contain 8½ hours less, *i.e.*, the year will be past before the last 8½ hours of the 365th day has flown; for 365 times 86 seconds = 8½ hours.) This result is evidently much too great even on Kant's standpoint; specially because in dealing with the question of the time, he commits an essential error in that he does not calculate according to correct mechanical principles, the force of the

Earth in its rotation, or the rotational effect of the Earth—apart altogether from the assumption here made that the density of the Earth is the same as that of the water. Kant does not disguise the incorrectness of this assumption; but the mean density of the Earth was not yet known, as it was first determined by Cavendish in 1793. Moreover, Kant consoles himself in connection with these and other assumptions of his, by holding that they would in some measure compensate for each other, because of their diverging on opposite sides from the truth. (It is hardly possible to follow Kant's calculation, because he has not specified all the numbers that are brought into it, and those stated can hardly be all correct—although they are quite the same in two editions which I have compared. For Mathematical readers the following statement may be given, as containing in it *all the data* which Kant adduces. Kant aims primarily at calculating the *onset or rush of the ocean against a coast extending from Pole to Pole*, the east coast of America being viewed as prolonged to both Poles, whereby the projecting point of Africa, and the eastern coasts of Asia, are more than compensated for. He does not say whether he has taken as the length of coast 2,700 miles, or whether on account of the sinuosity of the coasts, he has adopted a larger number. The height of the surface which the land presents to the onset of the water, he takes, reckoned in perpendicular depth, as 600 Paris feet, or 100 fathoms; and, finally, the velocity of the movement of the Sea from east to west under the Equator at one foot in the second, and as diminishing towards the Poles just as the movement of the parallel circles (*i.e.*, in every parallel circle, according to the proportion of its magnitude to that of the Equator, as less in the former than in the latter). Then the pressure of the Sea upon the surface of the land opposite to it, will have to be put as equal to the weight of a body of water whose basis is the whole surface pressed upon from Pole to Pole, and its height $\frac{1}{224}$ foot. This latter number is peculiarly puzzling; for as it must contain the velocity of the equatorial current, it cannot well be anything else than the falling height corresponding to the mean velocity of that current, according to the formula $v^2 = 2gh$; but if this mean is put $= \frac{1}{2}$, then the formula gives $h = \frac{1}{240}$ (for $g = 30$), and if this is put more correctly as $= \frac{2}{\pi}$, we get $h = \frac{1}{15 . \pi^2} = \frac{1}{148}$. For the circumference or the radius of the Earth in miles, Kant could have no other numbers than those we now have, but he would have the length of the mile in Paris feet—which, however, he does not state, although the magnitude of that body of water and its proportion to the magnitude of the Earth depends thereon. And when he says that the body of water calculated by him at 1,100,000 cubic fathoms is exceeded by the Earth 123 billion times, we find it rather 132 billions—the mile being taken = 22,800 Paris feet. Finally, when Kant under the assumption already noted, that this proportion of the volume is at the same time the proportion of the weight, finds those two million years, it is to observed that in round numbers, four million years = 132 billion seconds; and, therefore, Kant seems to have concluded that because the pressure per second of his body of water is exceeded 123 billion times by the weight of the Earth, the half (?) of the 123 billion seconds is required to exhaust the force of the earth, *i.e.*, as already observed, to double the time of the axial rotation. Now, I cannot understand that division by 2—which should rather be a multiplication by 2—nor can I harmonise this reasoning with a subsequent remark of Kant that the force of the Earth has been taken into calculation as that of a globe shooting along with the velocity of a point under the Equator (?).

'However, the exact ascertainment of the amount of resistance, especially on account of the irregular partition of the solid and fluid on the surface of the Earth, is connected with almost insuperable difficulties, whether on the standpoint of Kant or of Mayer. Mayer has also attempted an approximate estimation of the retardation, and has reasoned from it, according to correct mechanical principles, to the result for the lengthening of the Star day; and in this he has corrected Kant as much as in the theory itself. He believes that the retarding pressure at the lowest positions must be estimated at not less than 1,000 million kilograms, and finds, according to the rules of mechanics, that the lengthening of the time of the Earth's rotation in 2,500 years—supposing that the volume of the Earth remained unaltered during that period—must amount to $\frac{1}{16}$ second, and, therefore, in 2,000 years it would be $\frac{1}{20}$ second—for which Kant had given 86 seconds. (Kant's "body of water" reduced to weight gives 10,300 million kilograms. As, according to Mayer, the east-westward pressure of the upper tidal mass is related to the west-eastward of the lower, as 14 to 13, the difference thereof is $\frac{1}{27}$th of the total pressure which Kant brings into calculation, and Kant's number should be just 27 times, while it is only 10 times that of Mayer. But notwithstanding this, Kant finds for the increase of the Star day in 2,000 years 1,720 times as great a number as Mayer, from which it appears most clearly that he made a second essential error in passing on to the time. Mayer determines the effect of the Earth's rotation—always under the assumption of a uniform density of the Earth—at 25,840 quadrillion kilogram-metres, while its weight-metre amounts to $6\frac{3}{4}$ quadrillion kilograms.) If we compare Mayer's result with the empirically proved increase of the Star-day, which amounts to only $\frac{1}{86}$th second in 2,000 years, it is about four times the latter amount. Supposing now that the theoretical result is only half correct, so that it is only considerably greater than the empirical result, it follows that a considerable part of the resisting force must be spent in *compensation of an opposite cause*, which would shorten the time of the Earth's rotation. Mayer finds this opposite cause in the *diminution of the volume of the Earth*, in consequence of the excess of the radiation of its own heat over the inflow of heat from the Sun. We cannot, however, enter further here on the numerous considerations and facts which Mayer adduces in the last chapter of his *Dynamics of the Heavens* to corroborate this view of the *net loss of the Earth in heat*; but the weight of his considerations is certainly not to be under-estimated.'[1]

3. Kant's Discussion of the Ageing of the Earth.

Later in the same year 1754, Kant contributed another paper to the same Königsberg journal, which was entitled, 'The question: Whether the Earth grows old? physically considered.' It appeared in sections, from Number 32 to 37, and therefore in August and September, 1754.[2] This discussion shows the same original and suggestive insight on the part of Kant, although it is less definite in the way of positive result. Its value seems to me to be generally underestimated by its critics. It is really the first clear discussion of the *method* of determining the age of the Earth by observation of its actual changes as now going on; and it presents a distinct view of the universal significance of the

[1] '*Kant und die Naturwissenschaft.*' *Deutsche Vierteljahrs-Schrift.* No. CXXII., 1868. Pp. 76-80.

[2] *Königsberg Wöchentliche Frag- und Anzeigungs-Nachrichten*, Jahrgang, 1754, Stück 32-37. Reprinted in Nicolovius' *Sammlung*, S. 91-120, and in all the complete editions of Kant's Works. Cf. Borowski, *l.c.* 48-49. Here again V. Kirchmann in his *Erläuterungen*, does scant justice to Kant. Kant's discussion seems to me well worthy of translation, and some day it may be translated.

common, constant physical processes that have been effecting the great changes of the Earth's surface all along. Kant clearly states and discusses the four theories or causes assigned at that time to explain the gradual wearing out of the present terrestrial system, and the consequent ageing of the Earth; and even through his discussion of their imperfect data, while admitting the contingencies of occasional volcanic catastrophes, he anticipates the view of the relatively uniform action of the existing physical causes in altering the physical conditions of the Earth, as worked out by Lyell in his *Principles of Geology* nearly a hundred years later, and now adopted by all geologists and physiographers. He is particularly strong in his clear description of the influence of rain-water in denuding and lowering the upper lands, and thus forming lower fertile regions by the deposits of flowing streams. He does not attempt to determine precisely the Age of the Earth, but is content with merely indicating observations and investigations which are set in that direction, and which already virtually demonstrate not only the ageing, but the gradual dissolution of the present system of things. These two minor Essays of 1754 were really 'chips' struck off during the process of working out the Cosmogony; and the discussion of the Ageing of the Earth presents itself as the transition to the greater work, from the earlier announcement of it in the discussion of the Retardation of the Earth's Rotation.

V. Kant's 'Natural History and Theory of the Heavens.'

1. *Publication.*—The last word of the paper on the rotation of the Earth was the announcement of the forthcoming publication of the Cosmogony, which was printed and ready for publication in the spring

of the following year, 1755. Kant, however, did not adopt his proposed title, but dropping the general designation 'Cosmogony,' the title-page ran thus: 'Universal Natural History and Theory of the Heavens, or an Essay on the Constitution and Mechanical Origin of the Whole Universe, treated according to Newtonian Principles. Königsberg and Leipzig. Published by Johann Friederich Petersen, 1755.'[1] The book was a crown octavo of 200 unnumbered pages, anonymous, and yet dedicated to Frederick the Great. It had an untoward fate in the hands of the publisher. He became bankrupt at that very time, and his stock was 'sealed up' and legally appropriated, so that, as Borowski says: 'The work had the peculiar fate of not coming into the hands of the public nor even of King Frederick II., to whom it was dedicated, merely from the view that under the authority of the King more particular investigations regarding the system, by the learned men in Berlin and elsewhere, might be brought about.' The book thus remained for years entirely unknown, and this must have been a great disappointment to the young author, who was just preparing for his public career, and who, as Borowski tells us, 'sometimes regretted' the fact. The dedication to the

[1] 'Allgemeine Naturgeschichte und Theorie des Himmels oder Versuch von der Verfassung, und dem mechanischen Ursprunge des ganzen Weltgebäudes nach Newtonischen Grundsätzsen abgehandelt. Königsberg und Leipzig, bey Johann Friederich Petersen, 1755.'

King shows how conscious Kant was of the importance of the work. But the copies were not destroyed nor lost, and although the exact year of its subsequent publication cannot now be determined, yet the original edition did come into the hands of the public, and it must have been exhausted before the end of the century. I do not know of any copy of the original edition existing in this country, but copies of it remain in Germany, and the best recent editions of it (as those of Hartenstein, Kehrbach, and A. J. v. Oettingen) have been carefully collated with it, and its literary peculiarities indicated.

2. *Kant's Later Summary of the Work.*—In 1763 Kant published a philosophical treatise, entitled *The Only Possible Argument for a Demonstration of the Existence of God*, and in the seventh section of its second division, he introduced a summary of his ill-fated work of 1755, with an apology for its length in the preface, and with a distinct reference to it under its proper title in a footnote as 'having become little known.' The section is entitled '*Cosmogony.* An Hypothesis in the way of a Mechanical Explanation of the Origin of the Heavenly Bodies, and the Causes of their Motions, according to the previously established Rules.' The summary is lucid and comprehensive, and it was the means of bringing Kant into correspondence with the celebrated astronomer, J. H. Lambert, who, in his *Cosmological Letters* published two years before

(1761), had presented a similar theory regarding the constitution of the stellar system. Kant's Treatise was translated, along with other Essays, into English in 1798, but this sketch of his Cosmogony seems to have received no attention in England at the time.

3. *Excerpt Authorised by Kant.*—An Excerpt from the original work of 1755 was published, with Kant's sanction, in 1791 by J. F. Gensichen, along with a German translation from the English of three notable treatises by Sir W. Herschel, on the *Construction of the Heavens* (Nicolovius, Königsberg). This Excerpt extended to near the close of the fifth chapter, ending with the paragraph that closes in the following translation at the top of p. 129, and it included the new oral statement by Kant, which is given in the footnote. Gensichen states that 'Kant could not be moved to allow any more to be reproduced; the remainder contained, he said, too much that was mere hypothesis for him to be able to wholly approve of it still.' Kant's final imprimatur went no further than this Excerpt, but we easily see why he was suddenly pulled up at that point, and it is not to be inferred that he did not approve of a good deal that follows.

4. *Spurious Editions in Kant's Life-time.*—A new edition of the complete work appeared in Kant's life-time, but without his co-operation, in 1797, edited, with preface, by M. F. [M. Frege]. It was published professedly at Frankfurt and Leipzig,

but really at Zeitz. It is entitled: 'A New Edition, with the Author's Own New Corrections.'[1] But this is misleading, as it contains no additions or modifications by Kant himself, except the oral statement added to Gensichen's Excerpt of 1791. It professes, however, to modernise the language and revise the numbers, which makes it worthless as a text, and it adds a variety of footnotes of no great value. There are copies of this edition in the Library of the Royal Observatory, Edinburgh, and in King's College Library, Aberdeen. It was again reprinted after Kant's death in 1808 as a 'Fourth Edition' at Zeitz by Webel. There is a copy of this edition in the Advocates' Library, Edinburgh.

5. *Genuine New Editions in Kant's Life-time.*—The work was, however, reprinted 'in the original form' in 1797, in 'I. Kant's not yet collected small writings,' and again in 1799 in the first volume of Tieftrunk's Collection.[2] Since then the work has been reproduced in all the collected editions of Kant's works. (Rosenkranz, Hartenstein, Von Kirchmann.) Kehrbach's separate edition of the work in the Universal-Bibliothek shows his usual thorough-

[1] Allgemeine Naturgeschichte, etc., von Immanuel Kant. Neue Auflage, mit des Verfassers eigenen neuen Berichtigungen. Frankfurt und Leipzig, 1797. 130. 8°.

[2] *Immanuel Kant's früher noch nicht gesammelte kleine Schriften. Frankfurt und Leipzig*, 1797, XVIII., 130. 8°. *I. Kant's vermischte Schriften. Echte und vollständige Ausgabe.* Bd. I. Halle, 1799. 8°, S. 283-520.

ness and accuracy both in his preface and text.[1] The convenient and excellent edition of A. J. von Oettingen in Ostwald's *Classics of the Exact Sciences*, 1898, has also been already referred to.

VI. Kant's Cosmogony in its Historical Relations.

The historical significance of Kant's Cosmogony will be best understood by indicating some of its most important relations to the past and to the present.

1. *Kant and the Ancient Cosmogonies.*—Kant is now recognised as the highest representative of the independent, free critical spirit of the eighteenth century. As such, he also exhibits its unhistorical character and its comparative indifference to the great thought-systems of the ancient world. Hence we do not expect or find any high estimate or appreciation of ancient thought in his early scientific period, which was entirely modern both in its interest and method. He admits, however, at the outset a certain resemblance between his own theory and that of Lucretius, Epicurus, Leucippus, and Democritus; in other words, he accepts the standpoint of the ancient Atomistic School generally, while carefully repudiating and refuting its Atheistic positions. He undoubtedly owed his

[1] Kehrbach collates the readings even more carefully than Hartenstein had done, and points out some curious verbal peculiarities in the original text, but these are of interest only to the German student.

sympathy with the Epicurean physics to Lucretius, who was his favourite classical poet, and whom he had studied so carefully in his student days that he could repeat long passages of his magnificent poem ever afterwards. The splendid imagery and the solemn grandeur of the Lucretian Cosmogony fascinated him, and we find them reflected in his own graphic and impressive prose. Even the details in the Lucretian view of the formation of the world reappear to some extent in Kant, but now divested of their mythic accompaniments and elucidated with all the logic and observation of the new Natural Philosophy. Thus, the *exiguum clinamen*—the slight inclination or deviation of the atoms or particles from the parallel in their fall through infinite space—which Lucretius, following Epicurus, had introduced into the system to account for the rise of human liberty out of the mechanical necessity of Nature,[1] is also introduced by Kant into his

[1] Sed ne mens ipsa necessum,
Intestinum habeat cunctis in rebus agendis,
Et devicta quasi hoc cogatur ferre patique,
Id facit *exiguum clinamen principiorum*,
Nec ratione loci certa, nec tempore certo . . .
Denique si semper motus connectitur omnis,
Et vetere exoritur semper novus ordine certo,
Nec declinando faciunt primordia motus
Principium quoddam, quod fati fœdera rumpat;
Ex infinito ne causam causa sequatur;
Libera per terras unde hæc animantibus extat,
Unde est hæc, inquam, fatis avolsa potestas?
Per quam progredimur quo ducit quemque voluntas.

De rerum natura, Lib. II., 283; 251.

system. But with him it is the result of the Newtonian force of repulsion acting between the minute particles of falling matter, and it is applied to account for the rise of the motions of rotation and revolution in the solar system, a view not presented in Lucretius. In 1755 Kant had probably little sympathy with any of the other ancient Cosmogonies; and the exploration and rehabilitation of the physics of the other Greek schools and thinkers, such as the Ionic and Pythagorean schools, Heraclitus, Empedocles, Plato, Aristotle, and the Stoics, in which Hegel so greatly delighted and excelled, had little or no meaning or interest for him. We know from the quotation and reference on p. 27 *infra*, that he had read the remarkable introduction to the English Universal History of 1736, "containing the Cosmogony, or creation of the world" (pp. 1-51), and it probably contained all that Kant then knew of the imaginative theories of his predecessors.[1] It ranges in a discursive but imperfectly informed way over the Cosmogonies of the ancient peoples—the Chinese, the Siamese, the Hindus ('the Brachmans'), the Persians, the Babylonians, the Egyptians, the Phœnicians, the Greeks, etc.; it then gives an account of the *Vortices* of Descartes, of Burnet's *Theory of the Earth*, and of Whiston's *New Theory*, and winds up with a vindi-

[1] *An Universal History from the Earliest Account of Time to the Present, the Introduction containing the Cosmogony, or Creation of the World.* 1736.

cation of the literal truth of the Mosaic Cosmogony. In all this 'farrago' Kant found himself at home only with Epicurus. But he quotes a remarkable sentence from it vindicating Descartes and his successors from theological blame because of their bold attempts to explain the formation of the Heavenly Bodies by merely Natural Laws; and he claims for himself the same right of freedom and independence in his own investigation.

2. *Kant and Descartes.*—The Middle Ages, the transition from the ancient to the modern world, were entirely ruled by the ecclesiastical authority of the so-called Mosaic Cosmogony. But the revolution of thought which was effected by manifold causes, and which is exhibited most emphatically in the Theology of the Reformation, received its clearest philosophical expression in Descartes, the founder of the Modern Philosophy, and the first methodical expounder of the absolute freedom of Reason. Descartes, the inventor of Analytical Geometry, was as great in mathematical science as in pure philosophy, and 'there can be no doubt that the first germ of the Nebular hypothesis is to be found in Descartes' *Principles of Philosophy*, published in 1644 (43 years before Newton's *Principia*).'[1] The still crude Cosmogony of Descartes is best known in connection with his hypothesis of *Vortices*, or whirling movements, arising in the

[1] Descartes' *Principles of Philosophy*, Pt. III., sect. 52, 122; cf. Geo. F. Becker, *l.c.* Professor Veitch translated only the first three sections of Pt. III.

original nebulous matter, by which he tried to explain the revolving and rotatory movements of the great bodies of the visible universe. Descartes' theory is too well known to need to be reproduced here,[1] but it may be recalled that it ruled the scientific reflection of the greatest mathematicians of the time, including even Huygens, Fermat, and Bernoulli, and that it was modified by Swedenborg in a Vortical Cosmogony of his own as late as 1734. But Newton's searching and powerful criticism gradually brought it into utter disrepute; and Kant seems to have entirely accepted Newton's criticism, and to have been otherwise uninfluenced by the Cartesian Vortices in detail.

3. *Kant and Newton.*—Newton's criticism of the Cartesian Vortices is presented in various passages of the *Principia*, but especially in the famous concluding scholium, which contains not only his rejection of Descartes' hypothesis, but a cautious outline of his own Mechanical Cosmogony.[2] It well illustrates his famous rule of method: *Hypotheses non fingo.* Newton goes as far as the Law of Attraction will carry him, but no further. It does not carry him beyond the bounds of the solar system, which is viewed by him as entirely isolated from the stellar universe beyond. And even in the solar system that great Law only explains why the

[1] Excellent accounts of it by M. Faye and Mr. Geo. F. Becker, *l.c.*

[2] See also *Principia*, Lib. II., 38, 40, 53, etc., and *Optics*, p. 311, 342.

Planets and their satellites are kept revolving in their orbits in constant periods by this obscure centripetal force; it does not explain how they are found to be moving round and round in these orbits, or how they acquired the tangential or centrifugal force by which Newton represented them as driven on. It was at this point where Newton's Law of Attraction stopped, and it failed to explain the revolutional and rotatory motions of the solar system. And Newton in the last resort could only explain them by the immediate interposition of God, who directly communicated these motions to the full-formed Planets and their attendants by impulses from without. In the devout recognition of God's miraculous agency, not only in creating the material of the solar system but in setting its motions agoing, Newton's Natural Philosophy came to a pause. So far as it went Kant accepted it in its entirety, but he was stimulated by the fertile idea of another English thinker to go far beyond it.

4. *Kant and Thomas Wright of Durham.*—To Thomas Wright of Durham undoubtedly belongs the bold and original idea of transcending Newton on his own lines, by carrying his conception of the finite solar system into the infinite world of the stars beyond it. Wright's speculations have extraordinary originality and merit, although accompanied with considerable arbitrariness and fanciful conjecture in detail. He was the first to pro-

pound the idea that the stars are not scattered without order or connection in space, but have a systematic arrangement or constitution, like the solar system, whereby they are all bound into one immense unity and connection. This view he published in 1750, in a work entitled *An Original Theory or Hypothesis of the Universe*, and it was a summary of this work, which appeared in a Hamburg Journal on 1st January, 1751, that set Kant athinking and led him to his more comprehensive speculations on the Cosmogony. Through its influence upon Kant, Wright's speculation and work have been rescued from the oblivion into which they had fallen, and they are now more or less familiar to English students of the subject. But I give in Appendix B the means of more exactly judging of Kant's obligations to Thomas Wright than has hitherto been available in English. My attention was drawn some time ago by the Librarian of the Edinburgh University to a manuscript copy in that Library of the very rare article of the Hamburg Journal of 1751, which summarised Wright's views, and which Kant read at that time, and I have translated it in that Appendix.[1] Kant himself has very frankly acknowledged his obligation to Thomas Wright in a way that was characteristic of him, and which earned

[1] The MS. in the Edinburgh University Library (Box 31) was, as I understand, copied from a copy brought by Professor Copeland from Göttingen, now in the Library of the Edinburgh Royal Observatory.

him afterwards the designation of the 'honourable Kant.' It is evident, however, that Kant had not the summary of the Hamburg Journal before him when he wrote, nor had he ever seen Wright's book, for he says (*infra*, p. 32): 'I cannot exactly define the boundaries which lie between Mr. Wright's system and my own; nor can I point out in what details I have merely imitated his sketch and have carried it out further. Nevertheless, I found afterwards valid reasons for considerably expanding it on one side.' The reader will now be able to judge of this for himself by comparing the First Part of Kant's work as here translated with the contents of Appendix B. Wright is now universally recognised as the originator of the 'disc' or 'grindstone' theory of the arrangement of the stars, which Sir William Herschel afterwards elaborated on the basis of more extended and accurate observations. Kant improved and simplified Wright's Theory in an independent way, and gave it a more exact scientific expression. But it has to be carefully noted that Wright's views are directly related only to the First, which is also the most formal, Part of Kant's discussion; although it must also be admitted that the more original discussion in the Second Part, which properly constitutes his Cosmogony, arose at least indirectly from the stimulus of Wright's suggestions. Wright thus stands almost exactly in the same relation to Kant's early scientific work as Hume does to his later philosophic speculation. He, too, awoke Kant from his dogmatic slumber, cast the suggestive thought into that fertile mind which was developed into this new scientific Cosmogony, and thus through Kant, Wright may be said to have become the founder of the modern stellar Physics with all its wonderful recent developments. The connection between Kant and Wright is of peculiar interest to English students of the subject. Thomas Wright is only now receiving a belated justice at the hands of contemporary English writers upon science, and but for the renewed study of Kant, which brought to light the peculiar obligation and the impetus he owed to Wright, he would probably have been altogether forgotten, as he had long been neglected, by his own countrymen. Professor De Morgan's article on this remarkable man of genius is reproduced in Appendix C, as giving a fair and competent statement of Wright's position and views. The biographical sketch of Wright contained in the *Gentleman's Magazine* for 1793, referred to by Professor De Morgan, and practically summarised by him, is too rambling and gossipy to be worth reproducing; but a faithful copy of the admirable portrait which accompanies it is given. One motive of this work has been to do justice to Thomas Wright, while furnishing the means for determining exactly what Kant actually owed to him.[1]

[1] Mr. Gore gives a good account of Wright's Views in his *Visible Universe*, Ch. XIII. Mr. Proctor and other writers also refer to them.

5. *Kant and Lambert.*—In 1761, six years after Kant's Cosmogony was elaborated in his *Natural History and Theory of the Heavens*, the distinguished Mathematician and Astronomer, J. D. Lambert, published his *Cosmological Letters on the Arrangement of the Structure of the World*,[1] which obtained considerable popularity at the time. It gave, as new and original, a view of the arrangement of the stars, closely resembling that of Kant. When Kant published the summary of his theory in his *Only Possible Proof* in 1763, he referred in a footnote to Lambert as having presented the same view as he had done, concerning the systematic Constitution of the Universe, the Milky Way, and the Nebulæ. He considers that his book had not become known to Lambert, and infers from the agreement of Lambert's view with his theory that it would yet receive more confirmation. There can be no doubt of the independence of Lambert and of his thoroughly good faith in asserting it. In 1764 a friend of Lambert showed him Kant's summary with its reference to his work, and next year Lambert wrote a letter to

Copies of Wright's *Original Theory* are not so rare as Professor De Morgan and Mr. Gore suppose. The University Libraries of Edinburgh and Glasgow have each a copy. The Edinburgh University Library has also a copy of Wright's *Clavis Cœlestis*, London, 1742. It is an ingenious *Synopsis of the Universe*, elaborately illustrated ; but it does not contain any hint of the later Theory of 1751.

[1] *Cosmologische Briefe über die Einrichtung des Weltbaues.* Ausgefertigt von J. H. Lambert. Augsburg bei Eberhard Kletts Wittib. 1761.

Kant, dated Berlin, 13th November, 1765, which puts the matter in the clearest light. Lambert says: 'A year ago Professor Sulzer showed me your *Only Possible Proof of the Existence of God.* It gave me pleasure to find in it a mode of thought so entirely similar to my own. . . I can say to you, sir, confidently, that your thoughts about the construction of the world were not known to me till that time. What gave occasion to my *Cosmological Letters*, as I tell it at p. 149, was this: that in the year 1749, on a certain occasion immediately after supper, and contrary to my custom then, I left the company in which I was at the time, and went into another room. I there wrote down my thoughts on a quarto page, and in the year 1760, when I wrote the *Cosmological Letters*, I had still nothing further on the subject in hand. In the year 1761, I was told at Nürnberg that some years previously an Englishman had printed similar thoughts in letters to certain persons, but that he had not had much success, and that the translation of his Letters, begun at Nürnberg, had not been completed. I answered that I believed my *Cosmological Letters* would not make a great impression, but that perhaps in the future an Astronomer would discover something in the Heavens which could not be otherwise explained.'[1] Here we have Thomas Wright again, although Lambert acknowledges no obligation to him. Kant accepted Lambert's statement cordially,

[1] *Kant's Werke* (Hartenstein's Ed.), Bd. VIII., 652.

and there ensued a pleasant correspondence on Philosophical topics, in which Lambert was also keenly interested. Emphasising the remarkable similarity of Kant's mode of thought with his own, he even proposed that thereafter they should collaborate in their Philosophical work. But Kant did not accede to *that!* Their relations, however, continued most friendly ever after.[1]

6. *Kant and Sir William Herschel.*—A quarter of a century after Lambert's *Cosmological Letters* appeared, Sir W. Herschel worked out again, and again independently, a view of the 'Construction of the Heavens,' closely resembling that of Kant! But this time the view was founded on patient observation of the stars in the Milky Way with unprecedented telescopic powers, and it was presented as the result of induction from newly discovered facts. Sir W. Herschel says of himself: 'A knowledge of the Construction of the Heavens, has always been the ultimate object of my observations.' He presented his first views in two Memoirs, published in 1784 and 1785, entitled *On the Construction of the Heavens.* The view has been popularised by his son, Sir John Herschel, with his only too familiar illustration of the broad

[1] An abridged French translation of Lambert's *Cosmologische Briefe* was published by M. Merian under the title "*Système du Monde*," *par M. Lambert, publiée par M. Merian, de l'Academie des Sciences et belles Lettres de Berlin*, 2nd Ed., Berlin et Paris, 1784. Miss Agnes M. Clerke refers to an English translation entitled *The System of the World*, London, 1810. Mr. Gore gives an account of Lambert's Hypothesis.

knotched club, and is too well known as the disc 'theory' to require repetition here. Well did Kant say, with a certain prophetic forecast in 1755, that he already discerned the promontories of new lands to which others would yet give their names; for the name of Sir William Herschel, and not that of Kant or Wright, has become historically associated with this theory. It was in connection with the German translation of these Memoirs of Sir William Herschel on *The Construction of the Heavens* that Gensichen induced Kant to allow him to reproduce the corresponding portion of his *Natural History and Theory of the Heavens* in 1791, as mentioned above. Herschel's view may be regarded as so far an empirical verification of the speculations of Wright and Kant and Lambert, but it fell short of them in completeness and consistency. In consequence, Sir W. Herschel afterwards gave up his view, and about 1817 he practically abandoned it altogether, as has been shown by Struve and Proctor. Arago was perplexed by the fact that Herschel made no mention of Kant or Lambert.[1] It is difficult to believe that Herschel remained unacquainted with the views of Lambert at least, and such knowledge may have influenced him in his search for another representation. Sir W.

[1] 'Comment 29 ans plus tard *Herschel* abordant les mêmes problèmes, ne trouva-t-il jamais sous sa plume le nom du philosophe de Königsberg, ou du géomètre de Muhlhause? Ce sont des questions que je ne saurois résoudre.'

Herschel must undoubtedly be recognised as the greatest observational Astronomer of modern times, but his power as a constructive thinker in his own sphere was incomparably inferior to that of Kant.

7. *Kant and Laplace.*—In 1796, forty-one years after Kant had produced his *Natural History and Theory of the Heavens,* Laplace (1749-1827) set forth the first outline of his beautiful and fascinating Nebular Hypothesis in the last chapter of his popular *Exposition of the System of the World.* It was completed in the third edition (1808), by the addition of a paragraph on the formation of the planets by the rupture of the rings of vapour out of which they were formed. It remained in this form in the fourth edition of 1813; but in the fifth edition, the last published in his lifetime, evidently from regard to its hypothetical character, the exposition of the hypothesis was removed from the text and made to form the celebrated 'Note VII.,' and it is so reprinted in the sixth edition of 1836, nine years after the death of Laplace. The Hypothesis is also referred to summarily by Laplace in the fifth volume of the *Mécanique Céleste* (1825), in the last paragraph of the last chapter of Book XIV. It is expounded with all the lucidity and precision of Laplace's scientific style, but apologetically 'with the distrust which all that is not a result of observation or of calculation should inspire.' Notwithstanding this *caveat,* Laplace's brilliant

theory, recommended, as it was, by his great mathematical genius and undisputed authority, soon won large adherence; it long ruled with undisputed sway, and almost dogmatically, the domain of astronomical speculation; and notwithstanding the strong objections which have been accumulating against it, and the revival of Kant's better authenticated rival Theory, it still largely holds the field.

There is now no possible question as to the *priority* of Kant's speculation; but the question is still raised as to whether Laplace worked out his theory in entire independence and ignorance of Kant's earlier view. German writers have been occasionally inclined to question Laplace's independence and originality; but while Laplace had not the scrupulous literary conscientiousness of Kant, and while Zöllner reproduces in parallel columns passages from Kant and Laplace which have an astonishing agreement, the independence of Laplace is now generally admitted. The supposition that Laplace obtained some knowledge of Kant's views through the Cosmological Letters of Lambert, in the original German, or in the French translation, is quite untenable, and must be given up as erroneous. For even Lambert himself, as we have seen, knew nothing of Kant's views when he wrote them, and they are relevant only to Kant's discussion, founded on Wright, of the systematic constitution of the stellar universe, with which Laplace does not deal, and not to the Cosmogony proper, with which

Laplace's views so far agree. Liebmann has suggested that the general resemblance of the views of Kant and Laplace, so far as it goes, may be explained by the fact that they both started from Newton and Buffon, the crude theories of the latter being referred to by both; and it has also been well remarked by the German, v. Oettingen, that a gigantic intellect like that of Laplace did not need Kant's leading, but was sufficient of itself to account for his independent originality, as was the case with Lambert.

Laplace, in his own exposition, founds his hypothesis as to 'the cause of the primitive movements of the planetary system on the five following phenomena: the motions of the planets in the same direction and almost in the same plane; the motions of the satellites in the same direction as those of the planets; the motions of rotation of these different bodies, and of the sun in the same direction as their motions of projection, and in planes little different; the small eccentricity of the orbits of the planets and the satellites; lastly, the great eccentricity of the orbits of the comets, although their inclinations may have been abandoned to chance.'

The hypothesis of Laplace is too well known to require to be expounded here in detail, but we regret that considerations of space prevent the reproduction of it as in his own exposition, for the sake of accurate comparison with Kant's views. It has been always better understood than Kant's theory, and there are excellent summaries of it in our best text-books. Out of them all the following, by the competent hand of Professor Newcomb, may be quoted as particularly lucid in its statement of essential points:—

'Laplace was led to the Nebular hypothesis by considerations very similar to those presented by Kant a few years before. The remarkable uniformity among the directions of rotation of the planets being something which could not have been the result of chance, he sought to investigate its probable cause. This cause, he thought, could be nothing else than the atmosphere of the sun, which once extended so far out as to fill all the space now occupied by the planets. He does not, like Kant, begin with a chaos, out of which order was slowly evolved by the play of attractive and repulsive forces, but with the sun surrounded by its immense fiery atmosphere. Knowing, from mechanical laws, that the sum total of rotary motion, now seen in the planetary system, must have been there from the beginning, he conceives the immense vaporous mass forming the sun and his atmosphere to have had a slow rotation on its axis. The mass being intensely hot would slowly cool off, and as it did so would contract towards the centre. As it contracted its velocity of rotation would, in obedience to one of the fundamental laws of mechanics, constantly increase, so that a time would arrive when, at the outer boundary of the mass, the centrifugal force due to the rotation would counterbalance the attractive force of the central mass. Then those outer portions would be left behind as a revolving ring, while the next inner portions would continue to contract until, at their boundary, the centrifugal and attractive forces would be again balanced, when a second ring would be left behind, and so on. Thus, instead of a continuous atmosphere the sun would be surrounded by a series of concentric revolving rings of vapour.

'Now, how would these rings of vapour behave? As they cooled off their denser materials would condense first, and thus the ring would be composed of a mixed mass, partly solid and partly vaporous, the quantity of solid matter constantly increasing, and that of vapour diminishing. If the ring were perfectly uniform, this condensing process would take place equally all around it, and the ring would thus be broken up into a group of small planets, like that which we see between Mars and Jupiter. But we should expect that in general some portions of the ring would be much denser than others, and the denser portions would gradually attract the rarer portions around it until, instead of a ring, we should have a single mass, composed of a nearly solid centre, surrounded by an immense atmosphere of fiery vapour. This condensation of the ring of vapour around a single point would have produced no change in the amount of rotary motion originally existing in the ring; the planet, surrounded by its fiery atmosphere, would therefore be in rotation, and would be, in miniature, a reproduction of the case of the sun surrounded by his atmosphere with which we set out. In the same way that the solar atmosphere formed itself first into rings, and then these rings condensed into planets, so, if the planetary atmospheres were sufficiently extensive, they would form themselves into rings, and these rings would condense into satellites. In the case of Saturn, however, one of the rings was so perfectly uniform that there could be no denser portion to draw the rest of the ring around it, and thus we have the well-known rings of Saturn.

'If among the materials of the solar atmosphere there were any so rare and volatile that they would not unite themselves either into a ring or around a planet, they would continue to revolve around the sun, presenting an appearance like that of the Zodiacal light. . . . In accordance with the hypothesis of Laplace, it has always been supposed that the outer planets were formed first.'[1]

As regards the points of agreement between Kant and Laplace, M. Wolf says: 'These two conceptions have a common point of departure; both make the planetary system arise from a primitive Nebula whose motion commands that of the planets, and gives it that remarkable uniformity which demonstrates the common origin of these celestial bodies. It is entirely just to assign to the German philosopher the glory of having first announced this grand idea. But there exists no other common point between the two hypotheses; the Nebula of Kant differs entirely by its properties and its movements from the Nebula of Laplace. . . . Kant supposes the primitive universal chaos dividing itself, by the effect of attraction, into a great number of isolated masses, the germs of the future stars. . . . In every isolated

[1] *Popular Astronomy*, p. 495-7. J. S. Mill discusses the logical validity of the Nebular Hypothesis in his *Logic*, B. III., ch. xiv.; cf. John Fiske's *Cosmic Philosophy*, vol. I. (1874). There is an important mathematical discussion of the Nebular Hypothesis by David Trowbridge, A.M., in Silliman's *American Journal of Science and Arts*, beginning in No. 114 (November, 1864), which is well worth referring to. Mr. Proctor summarises the ring theory in a single sentence, thus: 'Laplace conceived that the solar system may have been formed by the gradual cooling and condensation of a vast, rotating nebulous globe; that in the process of contraction successive rings were thrown off, to form in one case a ring of small planets, but in general to break up and form each a single globe; that in the formation of such globes a similar process was repeated ending in the formation of satellites, and in a single case of what we now know to be a ring of small satellites.' —*Saturn and his System*, p. 202.

Nebula the internal actions are held to be sufficient to produce a regular movement of rotation of the whole. . . . This Nebula is formed of a central condensation around which particles independent of each other, forming a sort of dust matter, circulate in isolated orbits according to Kepler's laws. The Nebula of Laplace is a true atmosphere, formed of an elastic gas, whose entire mass turns with the same angular velocity as the central condensation, in virtue of an original movement whose cause—not indicated—is beyond the Nebula itself.' 'This Nebula differs essentially from that which Kant has placed at the basis of his system. Kant's Nebula is formed of independent particles which, originally in a state of repose, begin to circulate around the centre, each with its own velocity, determined by the law of areas. Laplace's Nebula is an *atmosphere*, formed of an elastic gas, all the layers of which are animated by the same angular velocity of rotation, and which is subject to all the laws laid down by Laplace in his study of atmospheres; it has a limit which is the point where the centrifugal force, due to its motion of rotation, balances the gravity; it has the form of an ellipsoid, whose oblateness cannot exceed one-third.'—*Les Hypothèses Cosmogoniques*, Ch. II. The two theories are thus contrasted by A. J. von Oettingen, who brings out a profound difference between them: 'Kant starts from the primitive Nebula in the Universe; Laplace from the Nebular disc of our Solar System already in rotation. Kant makes suns and planets arise out of certain regions of space, through gravitation; Laplace makes masses and rings detach themselves from the central body, through centrifugal force. Only in the case of Saturn does Kant make rings arise from the central body "through evaporation," in which case the vapours retain their tangential swing. Otherwise he assigns to every celestial body a certain zone of the vaporous space, out of which the matter is condensed into it. It is otherwise with Laplace, who starts from the contraction of the central body, with which its rotation must increase until the centrifugal force has become equal to the centripetal force, when with further contraction a ring shall then be detached; and this process is repeated several times. We hear often, perhaps from convenience, of a Kant-Laplace Cosmogony;[1] but the difference between them is sufficiently great to keep the views distinct and separate.'[2] We may also quote Mr. G. F. Becker's statement of the main points of comparison between Kant and Laplace: 'Kant begins with a cold stationary Nebula, which, however, becomes hot by compression, and at its first regenesis would be in a state of rotation. It is with a hot, rotating Nebula that Laplace starts, without any attempt to

[1] Helmholtz used this designation. So too F. Kerz in his *Plaudereien über die Kant-Laplace'sche Nebularhypothese*, 1887.

[2] Ostwald's *Klassiker Nr.* 12, p. 150.

account for the heat. Kant supposes annular zones of freely revolving nebulous matter to gather together by attraction during condensation of the Nebula. Laplace supposes rings left behind by the cooling of the Nebula to agglomerate, in the same way as Kant had done. While both appeal to the rings of Saturn as an example of the hypothesis, neither explains satisfactorily why the planetary rings are not as stable as those of Saturn. Both assert that the positive rotation of the planets is a necessary consequence of agglomeration, but neither is sufficiently explicit. The genesis of satellites is for each of them a repetition on a small scale of the formation of the system. Each refers comets to nebulous matter more distant than the planets, but Kant thought it merely the superficial portion of the Solar Nebula.' 'Comets were regarded by Laplace as little Nebulas formed outside of the Solar System, while Kant considered them as arising in the extreme portions of the Solar Nebula.'[1]

[1] We may also quote, as relevant here, what Mr. Becker says of Lord Kelvin's view: 'While Laplace assigns no cause for the heat which he ascribes to his nebula, Lord Kelvin goes further back and supposes a cold Nebula consisting of separate atoms or of meteoric stones initially possessed of a resultant moment of momentum equal or superior to that of the solar system. Collision at the centre will reduce them to a vapour, which then expanding far beyond Neptune's orbit will give a nebula such as Laplace postulates. Thus Kelvin goes back to the same initial condition as Kant, excepting that Kant endeavoured (of course vainly) to develop a moment of momentum for his system from collisions.' *l.c.* p. 108.

While these and similar comparisons have brought out more exactly the points of agreement and difference between Kant and Laplace, the progress of observational Astronomy has given rise to a number of very serious, if not absolutely fatal, objections to the plausible simplicity of Laplace's hypothesis, which, however, leave Kant's theory almost entirely unscathed. They are formulated and ably discussed on Laplace's standpoint by M. Wolf, whose discussion is summarily reproduced by Mr. Gore, and we may merely quote them from M. Wolf, without entering into his details. '1° The formation of the rings, such as Laplace supposes them, is impossible. 2° These rings could give birth only to a multitude of very small planets which would fill the whole extension of the primitive Nebula, and not to large planets separated by void intervals. 3° The planets born of these rings ought to have a retrograde motion of rotation. 4° The first satellite of Mars, and the inner rings of Saturn, are nearer their planets, and turn more rapidly than the hypothesis of Laplace allows. 5° The motions of the satellites of Uranus and Neptune are retrograde, as are also very probably the rotations of these planets.' These objections are undoubtedly very strong, and they might be multiplied. M. Wolf defends the hypothesis very ably from their application, but even *he* admits that one of them is 'capital,' and M. Faye was so impressed by another, viz.: the inconsistency of the facts founded upon in the fifth objection with Laplace's hypothesis, that he abandons it in its main points, and works out a modification of it which in certain respects approaches the theory of Kant. Other modifications have been ably advocated by Trowbridge, Newcomb, Roche, and others; but the inevitable consequence has been to bring the hypothesis itself more or less into disrepute, and to determine a reaction towards Kant's view. Newton himself was well aware of the common facts in the motions of the Solar System upon which Laplace founded, but he seems to have been deterred by the contradictions presented in the movements of the comets, from hazarding a conjecture as to a common physical origin of these common motions. Laplace only evaded the difficulty by removing the comets originally from the Solar System, whereas Kant's theory is quite compatible with his view of their primarily belonging to it. Again, Laplace's hypothesis is inconsistent with the later views now generally received as to the more recent origin of the great superior planets. For, according to Laplace, the most distant planets must be the oldest, as first formed in the process of the nebular contraction, whereas, according to Kant, some of them are, like the moon, of more recent origin than the earth, and he was apparently the first to maintain that Jupiter is still in a fluid state. Moreover, Laplace's view is much more incompatible than Kant's with the modern Thermodynamics. It is more assumptive, and shows no such insight as Kant does, into the genesis of additional heat by the process of contraction; and it presents no attempt to account physically for the movements of rotation. On almost every important point at which Laplace's hypothesis has been called in question, Kant shows a singular freedom from mere theoretical prepossession, and a remarkable conformity with the latest empirical observations, or at least a remarkable adaptability to them. This is shown particularly by the general harmony and correspondence of his views with the various modifications of the recent so-called 'Meteoritic Hypothesis.'[1] And Kant transcends Laplace, even more than in his empirical accuracy, by the universal range of his speculation, carrying it, as he does, into all the Stellar Systems, whereas Laplace stopped short at the Solar System as Newton had done; and this gives Kant's theory of evolution its supreme, unrivalled significance for us still.

A. MEYDENBAUER, a strong advocate of Kant and of the Meteoritic Hypothesis, points out 'the following contradictions of Laplace's theory with facts, and with rational inferences: 1° The primitive ball of Laplace is very hot and endowed with a rotation working equally through the whole ball, which is not accounted for; 2° the formation of equivalent double and plural stars is impossible according to the theory of the separation of rings; 3° in the whole

[1] See Lockyer's *The Meteoritic Hypothesis: A Statement of the Results of a Spectroscopic Inquiry into the Origin of Cosmical Systems*, 1890. But Sir Norman Lockyer's method here does not lead him to refer to Kant.

region of the stellar world known to us, only Saturn is provided with a ring system, while all the intermediate stages from the original process of agglomeration through the formation of rings and satellites are not represented; 4° with the exception of the asteroids, and in their case very conditionally, there is no example known in which a plurality of satellites move at nearly the same distance from the central body; 5° the axis of most of the planets have an inclination to the plane of their path, that of Uranus being apparently even perpendicular to it. If the planets and moons have received into them the sum of all the moments of motion contributed to the rings thrown off, then their axis of rotation must naturally be perpendicular to the plane of the ring, or, later, that of the path. The actual inclinations compel us to assume irregularities which are not founded in the process as a whole; 6° the Laplace theory is still owing a demonstration of the origin of comets and meteors; 7° the mere existence of a Mars moon, whose period of revolution is shorter than the planet's period of rotation, and yet in harmony with Kepler's laws, of itself alone overthrows the whole theory of the separation of rings; and the same follows from the mere fact of the *retrograde* motion of a moon of Uranus.'—*Kant oder Laplace*, p. 2.

8. *Kant and Cosmic Evolution.*—Kant is undoubtedly to be regarded as the great founder of the modern scientific conception of Evolution. There were vast conceptions of the evolution of the world even in ancient times, worked out by the thinkers of India and Greece, but their ideas were mostly mere products of the imagination, often extremely fantastic, and, at the best, pantheistic, vague, and unverified. Nor did any of the modern predecessors of Kant—

not to speak of the Mediæval Mystics—attain to much more definite ideas regarding the development of the universe. Descartes' Vortices, although an ingenious hypothesis, was not worked out into the detail of a system; and Leibnitz's Monadology and Pre-established Harmony, although involving a lofty spiritual view of the world, cut itself away from the first from all real physical connection. Newton, again, was too resolutely opposed to hypotheses not directly founded upon empirical facts, and too anxious to keep within the limits of exact calculation, to give reins to his imagination in the physical sphere. But Kant, gifted with a rare combination of empirical observation and speculative thought, was specially equipped with a genius that could grasp and combine the 'two worlds' in one. And so he first truly discerned the evolutional process of Nature in its universal range, and gave it corresponding scientific expression. In the work with which we are now dealing, he exemplifies this great idea as holding in the whole sphere of inorganic or 'pre-organic' Nature, and he is thus the greatest of all the pre-organic evolutionists. But even at this stage he did not stop here, but indicated, at least, that the idea of evolution was equally to be applied to the organic world, although he well knew that 'it is more difficult to explain the genesis of a worm than the origin of a world.' His evolutionary theory was thus co-extensive with the universe, and included all its parts and all its developments. He was thus the precursor in the Eighteenth Century of Herbert Spencer and Darwin in the Nineteenth; but he was greater than both, in that he established the general principles of which they have only given particular expressions, and in that, through the whole evolutionary process, he found an ultimate absolute principle, which at once transcends and comprehends it all. *The Natural History and Theory of the Heavens* is thus pregnant with the idea of a universal evolution; and, following out the later stages of his thought, we find that it really constitutes the most enduring conception of his philosophy. But, in order to find it, we must look through and beneath the elaborate formalism of his later mode of thinking, till disentangling himself, so far, from the fruitless abstractions of the 'mere vain dialectic art' in which the Critique of the Pure Reason terminates, he grasps all the more firmly the profound conception of Humanity, which was implicitly involved in all his earlier thinking, and stands before its majesty and infinity with a new sense of awe. He then comes to see the whole purpose of the universe in the light of the practical reason, and finds the order of the primary creation in Nature, which had been the first subject of his scientific investigation, consummated by the creative function of man, through the moral causality of his rational will. According to Kant, *the cosmic evolution of Nature is continued in the historic development of humanity and completed in the moral perfection of the individual.* This is the largest and the most valuable thought in

Kant's philosophy. It combines all the parts of his system into unity; it enables us to distinguish the essential from the accidental in his development and expression; and it furnishes the criterion by which his place is to be determined as the founder of a new period in the philosophical and scientific history of the world. So large is Kant's system of thought, when looked at from the scientific point of view, and so completely does it still furnish a framework into which the whole scientific knowledge of our time may be methodically set.

9. *The Ultimate Problem left Unsolved by Kant.*—It could not escape the penetrating mind of Kant that, with all the comprehensiveness of his fundamental point of view, there yet lay questions and problems behind and beyond it. The 'Chaos' from which he starts is not in itself intuitively intelligible, nor is it an absolute ultimate; it is only a relative ultimate to the existing system of things. It comes in 'in the middle of a process,' when the actual matter of the universe is found at its widest diffusion, and in a heterogeneous state, making space to be what Lockyer calls 'a meteoritic plenum,' the *prius* only of the existing order. Kant represents this Chaos as existing really but for a moment, as having come out of a prior condition of things, and as having already actually in it the forces of attraction and repulsion which, acting under their own special laws, begin at once to reduce it to a new order, and to maintain it in that order. Here Kant revives the ancient idea,

so vividly depicted by Lucretius, of a succession of finite worlds, each arising, like the Phœnix, out of a death and dissolution of the former, and containing in it, in new combination and form, the same eternal material atoms. Kant, indeed, powerfully describes the dissolution and palingenesis of worlds, but all this is only hypothetical; his theoretical analysis of the existing system could not actually carry him beyond its initial Chaos. He could not but see, even then, that an infinite succession of worlds, under reference only to themselves, is unthinkable, and that any attempt to explain things on that basis is but reasoning in a circle, and holds no real explanation in it. But the scientific resources of the time could carry him no further.

It was reserved for the nineteenth century to take up the ultimate problem of the *Pre-nebular Condition of Matter*, and we cannot blame Kant in any way for stopping where he did. This ultimate problem, indeed, has only been taken up of late years, and we are just beginning to reach some tentative solutions of it. It evidently involves the fundamental questions of the genesis of the chemical elements, the formation of material particles, the ultimate constitution of all matter, and the mode of its primordial distribution and arrangement in space; and all these questions ultimately run up into the question of the *Ether* as the primary basis and constituent, in its modified forms, of the material universe. It is not necessary to enter here upon the recent discussions and theories of the pre-nebular condition of the universe as we find them in 'the researches of Prout, Newlands, Mendelejeff, Meyer, Dumas, Clarke, Lockyer, Crookes, Brodie, Hunt, Graham, Deville, Berthelot, Stoney, Reynolds, Carnelley, Mills, and others,' which, according to Dr. Croll, 'clearly show that the very matter forming this nebulous mass passed through a long anterior process of evolution.'[1] Yet Kant in his later work, *Metaphysical Principles of Natural Science*, following in the footsteps of Leibnitz and Boscovich, laid down the Dynamical Theory of Matter which is presupposed in all these discussions, and which has been developed with such penetration and ingenuity in the theory of the 'vortex-atom' by Helmholtz and Lord Kelvin.[2] Kant must have seen that his whole mechanical theory of the evolution of the world, and even his moving forces of Attraction and Repulsion, must depend upon the potentialities of the primary constitution of matter; but, under the scientific limitations of the time, he had to leave the dynamical theory in a mere general definition to

[1] *Stellar Evolution* (1890), p. 107. But Dr. Croll does more than merely refer to these names. In an interesting chapter on 'The Pre-nebular Condition of the Universe,' he gives an excellent account of the views of Winchell, Morris, Grove, Brodie, Sterry Hunt, Lodge, Crookes, Clarke, Stoney, as well as of his own Impact Theory, in this relation.

[2] See the admirable account in the last two lectures on the 'Structure of Matter,' in Professor Tait's *Lectures* (1876); and Lord Kelvin's volume on 'The Constitution of Matter,' in his *Popular Lectures and Addresses*, vol. I., 1889.

his successors. We at least see that all the results they have reached as yet are quite compatible with his fundamental view, which practically assumed and even implies them. Kant, having thus reached the last term of his scientific analysis, like all clear thinkers, could not rest in the finite material process, but was driven by a necessity of thought to postulate GOD as the ultimate condition of that process and the First Cause of the whole system. Accordingly, he founds the whole upon God, starting from Him and coming back to Him as the first and the last thought of the whole world-order. This brings us to the relation of Kant's Cosmogony to Theology, as he then apprehended it.

VII. Kant's Cosmogony in Relation to Religion and Theology.

There is a celebrated anecdote told of Laplace to the effect that when he presented the first edition of his *Exposition du Système du Monde* to General Napoleon Buonaparte, then First Consul, Napoleon—himself a considerable mathematician—said to him: 'Newton has spoken of God in his book. I have already gone through yours, and I have not found that name in it a single time.' To which it is stated that Laplace replied: 'First Citizen Consul, *I have not had need of that hypothesis.*' This has been generally taken to mean that Laplace regarded the existence of God as an hypothesis.

M. Blanchet gives the story in the preface to his translation of Lucretius, and represents Laplace as proclaiming himself to be an Atheist. M. Barthélemy Saint-Hilaire, in the Preface to his translation of Aristotle's *Treatise on the Heavens*, takes the same view, and argues earnestly against it. But M. Faye gives the saying a different interpretation, and exonerates Laplace entirely from the charge of Atheism. He holds that it meant only that Laplace did not accept Newton's hypothesis of the *intervention* of God, from time to time, to modify the movements of the world, especially in its perturbations, 'and that he (Laplace) had not had need of such a supposition.' It was not God that he treated as an hypothesis, but his direct intervention at a determinate point. In support of this view, M. Faye maintains that Laplace 'did not profess Atheism,' and he tells us, on Arago's authority, that shortly before his death he begged that the anecdote be suppressed. Nor were his last pathetic words, 'ce que nous connaissons est peu de chose, ce que nous ignorons est immense,' those of a dogmatic Atheist; much rather do they remind us of the intellectual humility of Newton.

However it may have been with Laplace, there can be no question of the sincerity of Kant's Theism from first to last.

At this early stage of his thought, as all through, the existence of God and the rationality of Religion were in fact of supreme interest with Kant. And so at the very outset of his speculation, he secures its Theistic basis, and will not advance a step till he has firmly established the harmony of the mechanical process of evolution with the being of God. He, indeed, like Laplace, regards the mode in which Newton brings in the interposition of God, in a special act, to help him out of the insufficiency of his physical explanation of the world, as weak and untenable; but, at the same time, he carries the whole evolutionary process up to God, and finds it utterly unthinkable without God. It is not the exceptional physical fact, as such, but *all* facts, whatever be their nature, that prove the existence of God, according to Kant. The pulse of his argument, at this stage, is *the empirically proved predetermination of all matter* to bring forth and realise certain beautiful results and good ends, according to a perfect prior plan. '*There is a God, just because Nature, even in chaos, cannot proceed otherwise than regularly and according to order*' (p. 26). And so he lays the basis of the true, modern scientific Proof of the existence of God. We cannot do better here than quote the words of M. Wolf, who otherwise stands so strongly for Laplace rather than for Kant. 'I also recommend,' says M. Wolf, 'the reading of Kant's Preface. In dealing with Cosmogony, says M. Faye, it is difficult not to shock sentiments that deserve respect. It belongs to the philosopher to show how the tendency of the scientific mind to carry back the divine intervention to the last limits, and even to chaos, is to be reconciled with the higher notion of Providence. Above all, it has to be shown that our tentative Cosmogonies shake in nothing the demonstration of the existence of God, drawn from the wonders of the Heavens. Kant's Preface has done justice, a century and a half ago, to the objections which a false philosophy may raise against the efforts by which science seeks to explain the work which God has delivered to our discussions; and on that ground this Preface should be regarded as *the* Preface to all Treatises on Cosmogony.'[1]

All true scientists of the present day will sincerely echo these words of M. Wolf. I am one of those who believe that Atheism is entirely inconsistent with true knowledge of science; it is the vaunt only of the unscientific, the mark on the forehead of the mere sciolist who is incapable of ultimate thinking, or who has never risen to *the new scientific conception of God*, which Kant here indicates. 'It is true,' says Bacon, 'that a little philosophy inclineth man's mind to Atheism, but depth in philosophy bringeth men's minds about to Religion.'

Kant elaborated the same argument more definitely as 'the only possible Proof of the existence of God,' in his Treatise of 1761, in which he incorporated the summary of his Cosmogony. But, as is well known, one of the chief results of the 'Critique of Pure Reason' of 1781, was an ingenious and elaborate

[1] *Hypothèses Cosmogoniques*, IX.

attempt to demonstrate the invalidity of all the received proofs of the existence of God. He still speaks, however, with the greatest respect of the Physico-theological or Teleological proof, although he finds himself compelled by his new critical Philosophy, to let it also go. The subsequent work of his other two Critiques was mainly directed to correcting or modifying this position, so that, in a new statement of the Moral Argument on a higher plane, and in a transformation of the Teleological Argument as illustrated by living organisms, he won back again a rational faith in God. But all this does not overthrow his earlier position, and it is an utter mistake so to regard it; it only shows the limitation of his later critical philosophy, when his own subjective forms of thought—his inadequate categories—rose, like the folds of a dimming mist, between his inward eye and the external reality in the effected order of the Universe. Hegel has powerfully and profoundly dealt with Kant's sceptical dissolution of the proofs of the existence of God; it is one of his greatest achievements. But his own result is vitiated throughout by his identifying the absolute with the evolutionary process, or at least making the primitive Being of God the very Eternal Idea which passes entirely into it and through it, whereby he falls wholly away from the scientific distinction and the transcendent Theology of Kant's original Theism, loses the dividing yet connecting thought of creation, and virtually falls back on the standpoint of the Ancient Pagan

Cosmogonies, though in a purified and much higher form. Here again, then, we are forced to return—not merely to the Kant of the *Critique of Pure Reason*, but to the Kant of the *Natural History and Theory of the Heavens*, which thus becomes to the contemporary scientist a sort of new 'Book of Genesis.' And Religion, 'pure and undefiled,' on that basis, thus far still stands scientifically secure.

Nor does Kant leave us here with a mere abstract Deistic conception, with what Carlyle calls 'an absentee God.' While he will not allow the finite to be confused with the Infinite, nor to be negatively identified with it, nor to be reduced to a mere false abstraction, he yet holds that 'the field of the revelation of the Divine attributes is as infinite as these attributes themselves.' 'Creation is not the work of a moment.' 'The Deity is equally present everywhere in the infinitude of space; He is found equally near wherever there are natures that are capable of soaring above the dependence of the creatures to communion with Him as the supreme Being. The whole creation is penetrated by His energy.' He lives and moves by His power and laws in all things, ever renewing His work, but supremely 'in the perfection of creatures endowed with reason,' in man. 'He sees with equal eye, as God of all, A hero perish, or a sparrow fall.' The Infinitude of Space and the Eternity of worlds are the home of His omnipotence and omniscience, and He is the Parent of all good. The marvellous manifestations of His power do not blind the scientific eye to the gentle outgoings of His goodness; they only give them a wider and more varied range and a more certain embodiment. All is the realisation of an eternal plan, which advances from stage to stage on its sure prescribed way, and which must issue in a perfect result. 'The perishing of worlds' and the 'terrible catastrophes' of Nature but bring in a higher and better order; the goal comes ever more clearly into view. So Kant reaches his sublime contemplation 'of the Creation in the whole extent of its Infinitude in Space as well as in Time,' and exhibits it, in his seventh chapter, with a loftiness of conception and an imaginative grasp that 'takes in all Nature with an easy span,' and is not surpassed in its own way in all literature. And so when, on the latest stage of his thought, he had put forth all his power to establish the eternal basis of the spiritual life of man,[1] his mind seems to revert to the glory of his early vision, and he combines it with his moral conception in that well-known burst of high philosophic rapture: 'Two things there are, which, the oftener and more steadfastly we contemplate them, fill the mind with an ever new, an ever rising admiration and reverence;—the Starry HEAVENS *above*, the MORAL LAW *within!*' And both are God's—'of Whom, and to Whom, and through Whom are all things—Who is over all, God blessed for ever.' This *is* 'cosmic theism,' the only true basis of the reconciliation of Science and

[1] *Kritik der prakt. Vernunft*, *Beschluss* (1781).

Religion. The principle of their final harmony is already found here in Kant. Religion and Science are ultimately one; for the first word of Religion is also the last word of Science. And Science, as the latest revealer of the Divine Will, must be the chief new factor in the Theology of the coming centuries.

VIII. Kant's Scientific Achievement generally. Criticisms, Summaries, and Translations.

Kant's scientific achievement is, therefore, original, great, and enduring in all its relations. He was, in this connection, the historical successor of Copernicus, Kepler, and Newton; the true founder of Physical Astronomy in its widest range, and the interpreter of its highest spiritual significance. We are but beginning to understand the greatness of his conceptions, as he shines upon us again, full-orbed, in all his lustre, after long eclipse; and all the science of our age may still gather new strength and confidence from his bold thoughts and fruitful suggestions. There can be no doubt that he was specially endowed with the peculiar gift of the scientific mind, and that he used it to noblest purpose. Surveying his work, we may even say of him, too: '*Sibi gratulentur mortales, tale tantumque exstitisse humani generis decus.*' 'It cannot be denied,' says Helmholtz, 'that the Kant of early life was a Natural Philosopher by instinct and by inclination; and that probably only the power of external circumstances, the want of the means necessary for independent scientific research, and the tone of thought prevalent at the time, kept him to philosophy, in which it was only much later that he produced anything original and important. . . . He was restricted to the scanty measure of knowledge and appliances of his time, and of the out-of-the-way place where he lived; but, with a large and intelligent mind, he strove after such more general points of view as Alexander von Humboldt afterwards worked out. It is exactly an inversion of the historical connection when Kant's name is occasionally misused, to recommend that natural philosophy shall leave the inductive method by which it has become great to revert to the windy speculations of a so-called "deductive method." No one would have attacked such a misuse more energetically and more incisively than Kant himself, if he were still among us.' Surely all this must come straight home to the English student of science.[1]

Criticisms.—Criticisms of Kant's positions have gone hand in hand with the renewed interest of

[1] Helmholtz, *Popular Lectures*, Second Series, 1881, p. 141. Mr. Becker, referring to another Lecture, 'On the Interaction of Natural Forces,' delivered February 7, 1854, at Königsberg (translated by Professor Tyndall in the First Series), points out 'that it is certainly most curious that at a Kant celebration Helmholtz should have announced the rediscovery of four of Kant's theories.' (This lecture, however, was not delivered at 'a Kant celebration,' but was addressed to the Physico-economical Society of Königsberg, in promotion of a movement to erect a public monument to Kant. See Helmholtz's *Vorträge u. Reden*, 4 A. Bd. 1. Vorr.) No doubt Helmholtz had read

comparatively recent years. Naturally the leading critics have been the followers and vindicators of Laplace in France, and chief among them has been M. Wolf. M. Faye likewise criticises some of Kant's leading positions, as he does those of Laplace, in clearing the ground for his own modification of their theories. Perhaps the ablest and fairest criticism of Kant's views in English is that of Mr. G. F. Becker, to which reference may be profitably made. Helmholtz, Lord Kelvin, and Professor Tait have all written appreciatively of Kant's views, and have in some respects carried them out and brought them up to date in their own work. A severe test of Kant's theory of the origin of the sidereal system has come into play with the spectroscopic analysis of Kirchhoff, Huggins, and their busy followers; but its results are, so far, in entire harmony with Kant's view, and have only extended its range and certainty. Most of the criticisms that have been brought to bear upon Kant apply only to incidental assumptions, imperfections, or errors, which were more or less inevitable from the limited empirical knowledge and resources of his time, and they do not overthrow the cardinal and essential positions of his theory, which, as we have seen, is receiving fresh confirmation and increasing adherence in our day.

Kant, but he refers to him here somewhat generally, and does not clearly distinguish his views from those of Laplace. Dr. Adamson remarks that 'Helmholtz, like many other scientific writers [including Zöllner] seems to have owed his knowledge of Kant [*i.e.* of his philosophy] to Schopenhauer.'

Objections to Kant's Cosmogony.—It would be out of place in an Introduction, which aims only at making what follows intelligible in its historical relations, to deal in detail with the Objections to Kant's theory, referred to. Such a discussion would have to assume a knowledge of the contents of the work which we are merely introducing, or such an anticipative statement of the disputed positions as would carry us into too great detail. A brief indication of the chief objections may however be given, and must here suffice. M. Wolf puts them most succinctly when he alleges that 'the conceptions of Kant are too often in formal contradiction with the principles of mechanics.'[1] (1) 'Kant,' he says, 'supposes the universal primitive chaos dividing itself by the effect of attraction, into a large number of isolated masses, germs of the future stars, which remain in repose by the equilibrium of their mutual actions. Now such a system of masses devoid of initial velocity would gather, *perforce*, into a single mass.' This, however, is simply to ignore Kant's attempt to explain the tangential, or centrifugal motions, against which the following formidable objection is urged. (2) It is maintained, and very generally, that Kant has failed to account for the movements of rotation and revolution, which Laplace assumes as inherent in the nebular mass as a whole from the first. Kant conceives these motions as arising from the minute mutual repulsion of the particles, which make up the nebular mass, and their collisions as they fall through space, whereby they are deflected from the perpendicular, and gradually assume a revolving motion in orbits, at points where the falling matter becomes aggregated according to mechanical conditions. But this, as Mr. Becker puts it, is an attempt 'to create a moment of momentum' in a finite system, or to evolve a new force out of the existing forces which would

[1] *Hypothèses*, p. 19.

really be a positive addition to them. M. Wolf puts the objection thus: 'In every isolated nebula the internal actions are held to be sufficient to produce a regular motion of rotation in the whole mass. This conclusion is absolutely contrary to the laws of mechanics; the actual motions of the revolution and rotation of the sun and planets, can be only the equivalents, without augmentation or diminution, of the motion of rotation communicated originally to the nebula by an external cause.' This is practically to fall back upon Newton's position, and to discard entirely the ingenious explanation suggested by Kant. But the matter cannot rest there; nor does Laplace's assumption really lighten the difficulty. After all, we know too little of the action of the force of repulsion to justify us in either dogmatically asserting, or dogmatically rejecting, Kant's view; and the new theory of the 'vortex-atom,' and the tendency, in consequence, to revive in modified form the Cartesian vortices, point on the whole in Kant's direction. Moreover, other explanations of the rotatory motion, not inconsistent with Kant's process generally, have been suggested, such as the modification of the Impact Theory suggested by Lord Kelvin, according to which, if two solid globes collided with each other in space and 'if each had a transverse motion, in opposite directions, of 1·89 metre per second, the result would be a globe like our sun rotating in twenty-five days.'[1] It has occurred to me, although I cannot quote an authority in favour of the idea, that the objection would be met, if we supposed the generating nebula to be not simple and one, but compound and made up of two or more nebulæ which, by their mutual attraction had met and blended with each other in space, as may be the case with the Spiral Nebulæ, which seem to suggest such a formative condition. But the discussion of a multinebular

[1] *Good Words*, April, 1887.

origin of our solar system and the Pre-nebular conditions of matter, would take us too far afield. Kant's view is by no means overthrown by this objection; but it may require to be further determined, and it has many physical analogies and indications in its favour. (3) A third objection specially urged by M. Faye, and accepted by M. Wolf, is that the planets and satellites, if formed according to the ideas of Kant, would have a *retrograde* motion of rotation. But this objection seems to apply rather to the Ring theory of Laplace, from which M. Wolf has vainly striven to vindicate it, than to the meteoritic view of Kant; and a more precise discrimination of the two theories will also modify the incidence of the objection, or even entirely meet it. The other objections raised or hinted relate to mere incidental imperfections or erroneous conjectures rather than to any essential position in Kant's view. (4) Thus Kant's theory of the increasing eccentricity of the orbits of the planets as they get more remote from the sun, until they merge in a manner into the greater eccentricities of the comets—although it seems to have suggested his happy anticipation of the discovery of further planets beyond Saturn—does not hold true in detail, and is particularly contradicted by the orbit of Neptune, which is nearly circular. (5) Again, much has been made of the error he committed in his bold attempt to calculate the period of the diurnal rotation of Saturn from the nature and relation of its ring (pp. 118-9), which he made too small, just as he had made the retardation of the rotation of the earth too great. Here he makes the time to be 6 hours 23 minutes and 53 seconds. Afterwards, in the Summary of 1761, he made it 5 h. 40 m. But Sir W. Herschel determined it by actual observation to be 10 h. 16 m., and Mr. Hall has recently made it 10 h. 14 m. 24 s. M. Faye goes the length of saying that when the observation of Herschel shewed that Kant had made so great an error in his calculation, 'a veil was thrown over this affair out of regard, without doubt, for the celebrated philosopher of Königsberg.' But this is surely carrying the matter too far; the mistake was a venial one in the circumstances; and no one thinks of claiming for Kant, with all his speculative insight, the formal mathematical dexterity of Lagrange or Laplace. It may be noted that M. Wolf also points out a mistake in the calculation at the foot of page 91, where 'for 1,000 trillions ['bi-millions'] we should read 8,000 trillions, Kant having here confounded the diameter with the radius.' (6) M. Faye also objects to other numerical determinations and to the chapter on Comets as being 'embarrassed and confused.' But surely it is unnecessary to repeat or deal with such objections. Kant must be read and judged historically, and the more the limited and inadequate data furnished by the knowledge of his time are kept in view, the more will his work be appreciated and admired. From this point of view it is considered unnecessary even to point out the numerical and other statements in the text which have been antiquated by the progress of Astronomy; it must be unnecessary even for the general reader, and to the advanced student it would be only interruptive and irritating. (7) It is objected that Kant does not explain the origin and maintenance of the Sun's heat. But this again is unhistorical; it is like blaming Homer for not writing Paradise Lost, or—to take a more directly relevant illustration—it is like finding fault with Kepler for not having worked out Newton's law of gravitation. As a matter of fact Kant's view of the constitution of the Sun, as a central burning body, and of the origin of the Solar heat, was wonderfully correct and astonishingly in advance of his age. On this point he shines in contrast to Sir W. Herschel; and he even grasped the principle of the latest and truest explanation given by Helmholtz and Lord

Kelvin. And although it was then practically impossible to work out that principle in detail with the accuracy of Mayer and Joule, yet Kant's general theory is the one most compatible with their results. (8) Finally, it is needless to dwell upon such points as the possible explanation of the Flood by the breaking and falling upon the earth of a ring, which once surrounded it like that of Saturn, the point at which Kant, for an obvious reason, arrested Gensichen's Excerpt, or upon his speculation about the inhabitants of the other planets. The former is to be regarded as a mere imaginative idea, a fancy rather than a serious conjecture, which he would not revive. Nor is the latter, interesting though it be, an essential part of his system; it is expounded with a touch of irony, somewhat after the manner of Fontenelle, and it is presented by Kant himself as not coming within the range of exact scientific criticism.

Summaries and Translations.—There are now numerous excellent Summaries of Kant's theory in German, French, and English. Most of these have been already referred to, and out of them all I have selected for reproduction that of Dieterich, as the work of a careful student of Kant in his relation to Newton, and as giving a glimpse of his whole scientific thought in a systematic form. It is translated in Appendix A. The general reader, who may be approaching the subject for the first time, might do well to begin with this summary. He will also find excellent guidance to a rapid appropriation of Kant's view generally by turning to his own conspectus of the work at page 38.

But no summary, however accurate, can ever take the place of the original, or dispense the student from studying it in its detail. This is the *raison d'être* of this translation, which it is hoped will be helpful to the student who does not read German. It was undertaken and carried on so far before M. Wolf's French translation, already alluded to, came into my hands, but it has been referred to at important passages with advantage. M. Wolf's translation could not but be good, yet he acknowledges difficulties, and seems to falter at times before them. I have translated as literally as possible, and am not aware of having dropped a phrase or even a significant word. This translation contains all the scientific matter finally approved by Kant, as in Gensichen's Excerpt of 1791, and as it was very undesirable to stop just at that point, it goes somewhat further, giving all Chapter VII. and its important Addendum. With reluctance the translation of Chapter VIII., which is mainly a recapitulation, and of Part III., 'On the Inhabitants of the other Planets,' has been withheld, after Kant's example; but it is ready for the press, and will be given if another opportunity occurs. It is not of prime or essential necessity in studying the Cosmogony. The title 'Cosmogony' is used according to Kant's original intention, and his adoption of it in 1761. I cannot say that I have felt, like M. Wolf, 'the expression sometimes vague and badly defined,' or 'obscurities really existing in Kant's work.' Kant, indeed, does not write with the admirable lucidity and ease of Laplace, but he has greater strength, more intensity, richer poetic vision. He delights to quote Pope and v. Haller, his favourite English and German poets—Addison, too, once—and always with perfect aptness. I agree with Dr. Cairns that Kant 'never surpassed the style of this treatise.' It is clear, forcible, nervous throughout, and often rises in its physical descriptions to the picturesque and sublime. The description of 'a burning sun' at page 162 and of the rise and perishing of worlds, and his glimpses of cosmic scenery generally, are all masterly and impressive. Nor are they lacking in touches of humour, and startling effects produced by the contrast and blending of appropriate and telling imagery. Sir William Hamilton says it may be questioned whether Homer or Aristotle had the greater imagination; certainly we find the modern scientific imagination already here, at full vigorous play, in Kant. Among his other merits we may justly claim for him that he was the precursor of the popular scientific writer, and that in the exercise of the power of throwing a certain charm and fascination over profound scientific speculations he has not yet been surpassed.

I leave Kant in this connection with a greatly heightened estimate of his genius and marvellous powers. Every page of what follows shows the original and creative work of a master-mind, 'voyaging for ever through strange seas of thought alone.' Herein he laid the deepest and broadest basis for modern science that it has yet received, and it still stretches to the ever-widening horizon of man's knowledge of all Nature. It must be permanently associated with the continued progress of physical science hereafter, the surest guarantee of its perpetuity. But while recognising all this, I do not join in the regret of some recent scientific writers, hinted even by Helmholtz, that Kant should have ever left the domain of physical science to soar in the higher ether of pure speculative thought. This further movement was inevitable to him, and would have been taken, probably with other results, even without the awakening touch of David Hume. 'Nihil tetigit quod non ornavit.' Yet I am convinced that the *Critique of Pure Reason* would have been more truly scientific, more satisfying, and more lasting—if not more original and stimulating—had Kant kept in its prosecution more faithfully to the fundamental positions of his early scientific work. Absorbed in the forms of his own subjective perception and reflection, he shut out for the moment the great universe beyond, which gives them their true meaning and purpose, separating himself by a false abstraction from it, till the infinite space and time through which, in his youthful ardour, he had ranged with such freedom and power, shrank from their immensity and reality into the mere spectral phantoms of his own subjectivity. And so he became fatally entangled in his Paralogism and Antinomies which wound him round and round, and from which he never won entire freedom again. If we are now to correct the errors and excesses to which that false position led, both in himself and his great successors of the German speculation, we must turn back to his first vaster speculation as the condition both of a truer science and of a truer philosophy. Here we see him in the dawn of all his power, pluming his wings for his mighty flight through the vast universe of God, and soaring even beyond the flaming walls of the world—'the secrets of the abyss to spy.' For certainly *he* did inherit and did *not* lack—

> Nor the pride, nor ample pinion,
> That the Theban Eagle bear,
> Sailing with supreme dominion
> Thro' the azure deep of air.

Thus and there, in loftiest quest, I leave him with the Reader, who will surely follow him in his flight, with some of that admiration and sympathy which drew from Struve the appreciative and just judgment: 'Entreprise sublime, si elle n'est pas trop hardie pour l'esprit humain! En tout cas, l'astronome qui a lu l'ouvrage, s'il ne souscrit point à toutes les speculations qu'il renferme, ne s'en séparera sûrement qu'avec une vive admiration du génie et des vues surfois prophétiques de l'auteur.'

W. H.

UNIVERSITY OF GLASGOW,
September, 1900.

KANT'S PRELIMINARY DISCUSSION.

EXAMINATION OF THE QUESTION

PROPOSED
BY THE ROYAL ACADEMY OF SCIENCES AT BERLIN
FOR THE PRIZE FOR THE CURRENT YEAR:

WHETHER THE EARTH HAS UNDERGONE AN ALTERATION OF ITS AXIAL ROTATION.

1754.

Translated from the German.

WHETHER THE EARTH HAS UNDERGONE AN ALTERATION OF ITS AXIAL ROTATION.

THE judgment will shortly be announced which the Royal Academy of Sciences will deliver concerning the essays which have been put in competition for the prize in connection with their problem for this year. I have formed certain views concerning this subject; and as I have considered only its physical side, I should like to sketch briefly my ideas concerning it, having now seen that from its nature it is incapable of being brought on that side to the degree of perfection which the treatise must be expected to have which ought to carry off the prize.

The problem set by the Academy is expressed in the following terms: *Whether the Earth in its Rotation round its Axis, by which it brings about the alternation of day and night, has undergone any alteration since the first period of its origin. What may be the cause of this, and what can make us certain of it?* The question may be investigated historically. This might be done by examining the monuments of antiquity dating from the remotest times, as to the extent of their year and the intercalations which have been employed to prevent the commencement of it from moving through all the seasons, and comparing it with the length of the year as determined in our day. The object of this would be to see whether the year in the most ancient times contained more or fewer days, or hours, than it does now. In the former case the rapidity of the axial rotation would be proved to have been lessened, but in the second case increased, down to the present time. In my sketch I shall not attempt to obtain light on the subject by the aid of history. I find its record so obscure and its accounts so unreliable, as regards the question under consideration, that any theory which might be devised on that basis to make it accord with the principles of nature would probably seem to savour of the imagination. I shall therefore keep directly to nature, whose connections may distinctly indicate the proper result and give occasion to turn the observations drawn from history to the right side.

The Earth turns unceasingly round its axis with a free motion which, having been impressed upon it once for all at the time of its formation, would continue thenceforth unaltered for all infinite time and go on with the same velocity and direction, did no impediments or external causes exist to retard or to accelerate it. I proceed to show that such an external cause actually exists, and that it is really a cause which gradually diminishes the motion of the earth and tends even to destroy its rotation, in the course of immensely long periods. This event, which is destined some day to happen, is so important and wonderful that, although the fatal moment of its occurrence is so far postponed that even the capability of the earth to be inhabited and the duration of the human race will perhaps not reach the tenth part of that time, yet the mere certainty of this impending fate and the constant approach of nature to it, is an object worthy of our admiration and examination.

If the celestial space were filled with matter that offered some measure of resistance, the daily Rotation of the Earth in it would find a constant hindrance by which its rapidity could not but be gradually consumed and finally exhausted. But such resistance is not to be taken into account, since Newton has shown in a convincing manner that the celestial space, which allows a free unhindered motion to the light vapours of comets, is filled with infinitely less resisting matter. Besides this improbable hindrance, there is no other cause which can have an influence upon the motion of the earth but the attraction of the moon and of the sun; and as it is the universal driving power of nature—the power from which Newton has evolved her secrets in such a clear and indubitable way—it furnishes a reliable foundation upon which we may here base a sure examination and proof.

If the Earth were a wholly solid mass without any fluid elements, neither the attraction of the sun nor of the moon would do anything to alter its free axial rotation. For it draws the eastern as well as the western parts of the terrestrial globe with the same force, and causes thereby no inclination either to the one side or the other, and consequently it leaves the earth in complete freedom to continue its rotation unhindered, just as if it were subject to no external influence. But taking it to be the case that the mass of the planet comprises in it a considerable quantity of the fluid element, then the combined attractions of the moon and the sun, by moving this fluid matter, will impress on the earth a part of this agitation. The earth is actually found in such circumstances. The water of the ocean covers at least a third of its surface, and by the attraction of the said heavenly bodies it is kept in ceaseless motion—and it moves towards that side which is directed right opposite to the axial rotation. It deserves therefore to be carefully considered, whether this cause is not capable of bringing about some alteration of the rotation. The attraction of the moon, which has the greatest share in this effect, keeps the water of the ocean swelling incessantly, whereby it strives to flow to the points directly under the moon, both on the side turned to it and on that which is turned away from it, and thus to rise up; and because these points in the swell advance from east to west, they communicate to the ocean a constant onflow of all it contains in that direction. The experience of navigators has long since put this universal motion beyond doubt; and it is observed most distinctly in gulfs and bays, where the water increases its velocity from having necessarily to course through a narrow strait. Now, as this onward flow is directly opposed to the rotation of the earth, we have a cause upon which we can certainly calculate that it is incessantly exerted with all its power to weaken and to diminish that rotation.

It is true that if we compare the slowness of this motion with the rapidity of the earth, the slightness of the quantity of the water with the greatness of the globe, and the lightness of the former with the heaviness of the latter, it may appear that its effect might be held to be nothing. But, on the other hand, when it is considered that this rush is incessant; that it has lasted from the beginning of time, and will always go on; that the Rotation of the Earth is a free motion, in which the slightest quantity that is taken from it is lost without reparation, whereas the diminishing cause remains unceasingly active in the same strength, it would be a prejudice highly unbecoming in a philosopher to declare a slight effect to be insignificant when, by its constant summation, it must yet ultimately exhaust even the largest quantity.

In order that we may estimate in some measure the greatness of the effect which the constant movement of the ocean from east to west opposes to the axial rotation of the earth, we shall only calculate the onset which the ocean makes upon the eastern coasts of the continent of America; and we shall prolong its extension to both poles, while we shall more than abundantly compensate for what is wanting in that range by the projecting point of Africa and the eastern coasts of Asia. Let us put the velocity of the said ocean movement at the equator at one foot a second, let it decrease towards the poles proportionally with the parallel movement of the circles of latitude, and finally let the height of the surface which the solid land presents to the onset of the water, estimated in perpendicular depth, be taken at 100 fathoms; then we shall find that the force of the violence with which the ocean presses by its motion upon this opposing surface will be equal to the weight of a body of water whose basis is equal to the whole said surface extending from the one pole to the other, and its height $\frac{1}{224}$ of a foot. This body of water, which comprises eleven times a hundred thousand cubic fathoms, is exceeded by the magnitude of the terrestrial globe 123 bimillion times; and as the weight of this body of water always presses against the motion of the earth, we can easily find how much time must pass until this hindrance has exhausted the whole motion of the earth. For this there would be required two million years, if the velocity of the swelling ocean is assumed to continue the same to the end and the mass of the earth to be of equal density with the matter of the water. On this footing the said diminution does not amount to much; but yet in moderate periods, as, for example, within a range of two thousand years, the retardation would amount to so much that the course of a year would then be eight and a half hours less than before, because the axial rotation would have become so much slower.

The diminution of the daily motion is indeed subject to great limitations, for the following reasons: (1) The density of the whole mass of the earth is not, as was here assumed, equal to the specific gravity of the water; and (2) the velocity of the swelling ocean in its open expanse appears to be much less than one foot in a second. But, on the other hand, this want is abundantly compensated by the fact that (1) the force of the globe, which has here been calculated as rushing on in its movement with the velocity of a point under the equator, is only an axial rotation which is much less, and, moreover, the hindrance which is applied at the surface of a rotating globe has the advantage of leverage by its distance from the centre, which two causes taken together increase the diminution caused by the onset of the waters by $5\frac{1}{2}$; and (2), what is the chief consideration, this action of the moving ocean takes place not merely upon the inequalities that tower above the bottom of the ocean—the mainland, islands, and cliffs—but it is exercised upon the whole bed of the ocean. This action amounts, indeed, at every point to much less than the perpendicular onset of the former calculation; but, on the other hand, from the greatness of the range within which it takes place, which exceeds the formerly mentioned surface more than eight million times, it must be made up for with an astonishing surplus.

Accordingly, we shall not be able to doubt any longer that the everlasting motion of the ocean from west to east,[1] being as it is a real and considerable force, always contributes somewhat to the diminution of the axial rotation of the earth, the result of which must become infallibly perceptible through long periods. Now the evidence of history might justly be adduced to give support to this hypothesis; but I must confess that I can find no traces of an occurrence which may be so probably conjectured; and I therefore leave to others the merit of completing the subject by supplying this want when possible.

If the earth is approaching the cessation of its rotation with constant steps, the period of this alteration will be completed when its surface will be in relative rest as regards the moon, *i.e.* when it will turn round its axis in the time that the moon takes to revolve around it, and when it will consequently always turn the same side to the moon. This condition will be caused upon it by the motion of the fluid matter which covers a part of its surface only to a comparatively small depth. If it were fluid through and through to its centre, the attraction of the moon would bring its axial rotation in a very short time to this regulated

[1] There is here a manifest error in the text, which should read 'from east to west,' but the error has escaped the notice of all the editors—Rosenkranz, Hartenstein, Von Kirchmann—although the expression is given correctly by Kant twice in the preceding paragraphs. —Tr.

residue. This at once brings before us the cause that has compelled the moon in revolving around the earth to turn to it always the same side. It is not a preponderance of the parts turned to it over those that are turned away, but an actually uniform rotation of the moon round its axis, exactly in the time in which it revolves around the earth, that brings about this continual presentation of the same half of it to the earth. Hence it may be confidently inferred that the attraction which the earth exercised on the moon at the time of its original formation, when its mass was still fluid, must have brought the axial rotation —which this neighbouring planet may be supposed to have performed at that time with greater velocity—down in the manner indicated to this regulated residue. From this we also see that the moon is a later heavenly body, which has been added on to the earth after the earth had already passed through its fluid state and taken on a solid form; otherwise the attraction of the moon would infallibly have subjected it in a short time to the same fate as the moon has undergone from the influence of our earth. This last remark may be regarded as a specimen of a Natural History of the Heavens, in which the first state of nature, the production of the heavenly bodies and the causes of their systematic connection, would have to be determined from the indications or marks which the relations in the structure of the world exhibit. This speculation, which is the same on the great scale—or rather on the infinite scale—as the History of the Earth involves on the small scale, may be grasped in that wide extension with as much confidence as has been shown by the attempts made in our day to sketch such a view of our terrestrial globe. I have devoted a long series of meditations to this subject, and have combined them into a system, which will soon appear publicly under the title: *Cosmogony, or an Attempt to deduce the Origin of the Universe, the Formation of the Heavenly Bodies, and the Causes of their Motion, from the Universal Laws of the Motion of Matter, in conformity with the Theory of Newton.*

UNIVERSAL NATURAL HISTORY AND THEORY OF THE HEAVENS;

OR

AN ESSAY ON THE CONSTITUTION AND MECHANICAL ORIGIN OF THE WHOLE UNIVERSE

TREATED ACCORDING TO NEWTON'S PRINCIPLES.

1755.

Translated from the German.

To

THE MOST SERENE,

THE MOST POWERFUL KING AND LORD,

FREDERICK,

KING OF PRUSSIA, MARGRAVE OF BRANDENBURG, HIGH CHANCELLOR AND ELECTOR OF THE HOLY ROMAN EMPIRE, SOVEREIGN AND ARCH-DUKE OF SILESIA, ETC.

MY MOST GRACIOUS KING AND LORD, MOST SERENE,
MOST MIGHTY KING, MOST GRACIOUS KING AND LORD!

The feeling of personal unworthiness and the splendour of the throne cannot make me so timid and fainthearted, but that the favour which the most gracious of Monarchs extends with equal magnanimity to all his subjects, inspires in me the hope that the boldness which I take upon me will not be regarded with ungracious eyes. With the most submissive respect I lay herewith at the feet of your Royal Majesty a very slight proof of that zeal with which the Academies of Your Highness are stimulated by the encouragement and protection of their enlightened Sovereign to emulate other nations in the sciences. How happy would I be, if the present Essay should succeed in obtaining the supreme approbation of our Monarch for the efforts with which the humblest and most respectful of his subjects has unceasingly striven to make himself in some measure serviceable to the good of his country. With the deepest devotion till death,

I am,

YOUR ROYAL MAJESTY'S

Most humble Servant,

THE AUTHOR.

KÖNIGSBERG,
14*th March*, 1755.

PREFACE.

I HAVE chosen a subject which is capable of exciting an unfavourable prejudice in a great number of my readers at the very outset, both on account of its own intrinsic difficulty, and also from the way they may regard it from the point of view of religion. To discover the system which binds together the great members of the creation in the whole extent of infinitude, and to derive the formation of the heavenly bodies themselves, and the origin of their movements, from the primitive state of nature by mechanical laws, seems to go far beyond the power of human reason. On the other hand, religion threatens to bring a solemn accusation against the audacity which would presume to ascribe to nature by itself results in which the immediate hand of the Supreme Being is rightly recognized; and it is troubled with concern, by finding in the ingenuity of such views an apology for atheism. I see all these difficulties well, and yet am not discouraged. I feel all the strength of the obstacles which rise before me, and yet I do not despair. I have ventured, on the basis of a slight conjecture, to undertake a dangerous expedition; and already I discern the promontories of new lands. Those who will have the boldness to continue the investigation will occupy them, and may have the satisfaction of designating them by their own names.

I did not enter on the prosecution of this undertaking until I saw myself in security regarding the duties of religion. My zeal was redoubled when at every step I saw the clouds disperse that appeared to conceal monsters behind their darkness; and when they were scattered I saw the glory of the Supreme Being break forth with the brightest splendour. As I now know that these efforts are free from everything that is reprehensible, I shall faithfully adduce all that well-disposed or even weak minds may find repellent in my scheme; and I am ready to submit to the judicial severity of the orthodox Areopagus with a frankness which is the mark of an honest conviction. The advocate of the faith may therefore be first allowed to make his reasons heard, in something like the following terms:

'If the structure of the world with all its order and beauty,' he says, 'is only an effect of matter left to its own universal laws of motion, and if the blind mechanics of the natural forces can evolve so glorious a product out of chaos, and can attain to such perfection of themselves, then the proof of the Divine Author which is drawn from the spectacle of the beauty of the universe wholly loses its force. Nature is thus sufficient for itself; the Divine government is unnecessary; Epicurus lives again in the midst of Christendom, and a profane philosophy tramples under foot the faith which furnishes the clear light needed to illuminate it.'

Even if I found some grounds for this objection, yet the conviction which I have of the infallibility of Divine truth is so potent in me that I would hold everything that contradicted it as sufficiently refuted by that truth, and would reject it. But the very harmony and agreement which I find between my system and religion, raises my confidence in the face of all difficulties to an undisturbed tranquillity.

I recognize the great value of those proofs which are drawn from the beauty and perfect arrangement of the universe to establish the existence of a Supremely Wise Creator; and I hold that whoever does not obstinately resist all conviction must be won by those irrefutable reasons. But I assert that the defenders of religion, by using these proofs in a bad way, perpetuate the conflict with the advocates of Naturalism by presenting them unnecessarily with a weak side of their position.

It is usual to signalize and emphasize in nature the harmonies, the beauty, the ends of things, and the perfect relation of means adapted to them. But while nature is thus elevated on this side, the attempt is made on another to belittle it again. This admirable adaptation, it is said, is foreign to nature; abandoned to its own general laws it would bring forth nothing but disorder. These harmonies show an alien hand which has known how to subdue to a wise plan a matter that is wanting in all order or regularity. But I answer, that if the universal laws of the action of matter are themselves a consequence of the supreme plan of the system, they cannot be supposed to have any other destination than just to serve to fulfil the very plan which the Supreme Wisdom has set before itself. And if this is not so, would we not be tempted to believe that matter and its general laws at least are independent, and that the

Supremely Wise Power, which has known how to use it in such a glorious way, is indeed great, but not infinite; is indeed powerful, but not all-sufficient?

The defender of religion is afraid that those harmonies which may be explained from a natural tendency of matter, may prove nature to be independent of Divine Providence. He confesses distinctly that if natural causes could be discovered for all the order of the universe, and that if these causes could bring forth this order from the most general and essential properties of matter, it would be unnecessary to have recourse to a Higher Government at all. The advocate of Naturalism finds his account in not disputing this assumption. He heaps up examples which prove that the general laws of nature are fruitful in perfectly beautiful consequences, and he brings the orthodox believer into danger by adducing reasons which in the believer's hands might become invincible weapons of his faith. I will give some examples. It has often been adduced as one of the clearest proofs of a benevolent Providence which watches over men, that in the hottest climates the sea-breezes, just at the time when the heated soil most needs their cooling breath, are, as it were, called to sweep over the land and refresh it. For instance, in the island of Jamaica, as soon as the sun has risen so high as to throw the most unbearable heat on the soil—just after nine o'clock in the forenoon—a wind begins to rise from the sea, which blows from all sides over the land, and its strength increases in the same proportion as the height of the sun. About one o'clock in the afternoon, when it is naturally hottest, this wind is most violent, and it diminishes again as the sun gradually goes down, so that towards evening the same stillness prevails as at sunrise.

Without this desirable arrangement this island would be uninhabitable. The very same benefit is enjoyed by all the coasts of the lands which lie in the Torrid Zone. To them it is most necessary, because, as they are the lowest regions of the dry land, they also suffer from the greatest heat; whereas the regions which are found at a higher altitude in these countries, and which the sea-wind does not reach, have also less need of it, because their higher situation places them in a cooler region of the air. Is not all this beautiful? Are there not here visible ends which are effected by means prudently applied? But, on the other hand, the advocate of Naturalism cannot but find the natural causes of this phenomenon in the most general properties of the air, without needing to suppose special arrangements made for it. He rightly observes that these sea-breezes must go through such periodic movements although there were no man living on such an island, and indeed from no other property than that of the air, and even without any intention specially directed to that end referred to, as it is indispensably necessary merely for the growth of plants, and is brought about just by the elasticity and weight of the air. The heat of the sun breaks up the equilibrium of the air by rarefying that portion of it which lies over the land, and it thereby causes the cooler sea-breeze to drive it out of its position and to occupy its place.

Of what utility are not the winds generally to the earth, and what use does not the acuteness of men make of them! Nevertheless no other arrangements are necessary to produce them than those general conditions of air and heat which must be found upon the earth even apart from these ends.

'If you admit then,' the freethinker here says, 'that useful arrangements and such as point to ends can be derived from the most general and simple laws of nature, and that we have no need of the special government of a Supreme Wisdom, then you must in this see proofs by which you are caught, on your own confession. All nature, especially unorganized nature, is full of such proofs, which enable us to know that matter, while determining itself by the mechanism of its own forces, possesses a certain rightness in its effects, and that it satisfies without compulsion the rules of harmony. And should any one well-disposed to save the good cause of religion contest this capability in the universal laws of nature, he would put himself into embarrassment and by such a defence give unbelief occasion to triumph.'

But let us see how these reasons which, as used in the hands of opponents, are dreaded as prejudicial, are rather in themselves powerful weapons by which to combat them. Matter determining itself according to its most general laws by its natural procedure, or—if any one will so call it—by a blind mechanism, brings forth appropriate effects which appear to constitute the scheme of a Supreme Wisdom. Air, water, heat, when viewed as left to themselves, produce winds and clouds, rains, rivers that water the land, and all those useful consequences without which nature could not but remain desolate, waste, and unfruitful. But they bring forth these effects not by mere chance or by accident, so that they might just as easily have turned out harmful; on the contrary, we see that they are limited by their natural laws so as to act in no other way than they do. What are we then to think of this harmony? How would it be at all possible that things of such diverse nature should tend in combination with each other to effectuate harmonies and beauties so admirably, and even to subserve the ends of such things as are found in some respects outside of the sphere of dead matter (as in being useful to men and animals), unless they acknowledged a common origin, namely, an Infinite Intelligence, an Understanding in which the essential properties of all things have been relatively designed? If their natures were necessary by themselves and independent, what an astonishing chance; or, rather, what an impossibility would it be that they should so exactly fit in to each other with their natural activities and tendencies, just as if a reflective prudent choice had combined them!

Now then, I confidently apply this idea to my present undertaking. I accept the matter of the whole world at the beginning as in a state of general dispersion, and make of it a complete chaos. I see this matter forming itself in accordance with the established laws of attraction, and modifying its movement by repulsion. I enjoy the pleasure, without having recourse to arbitrary hypotheses, of seeing a well-ordered whole produced under the regulation of the established laws of motion, and this whole looks so like that system of the world which we have before our eyes, that I cannot refuse to identify it with it. This unexpected development of the order of nature in the universe begins to become suspicious to me, when such a complicated order is founded upon so poor and simple a foundation. But at last I draw instruction from the view already indicated, namely, that such a development of nature is not a thing unheard of in it; nay, that its inherent essential striving brings such a result necessarily with it, and that this is the most splendid evidence of its dependence on that pre-existing Being who contains in Himself not only the source of these beings themselves but their primary laws of action. This insight redoubles my confidence in the sketch of the system which I have drawn. My confidence increases with every step I make forward, and my timidity vanishes entirely.

But it will be said that the defence of this system is at the same time the defence of the opinions of Epicurus, which have the greatest resemblance to it. I will not deny all agreement whatever with that philosopher. Many have become atheists by the semblance of reasons which, on more exact reflection, would have convinced them most powerfully of the certainty of the existence of the Supreme Being. The consequences which a perverted understanding draws from unimpeachable principles, are frequently very reprehensible; and such were the conclusions of Epicurus, although his scheme exhibited the acuteness of a great thinker.

I will therefore not deny that the theory of Lucretius, or his predecessors, Epicurus, Leucippus, and Democritus, has much resemblance with mine. I assume, like these philosophers, that the first state of nature consisted in a universal diffusion of the primitive matter of all the bodies in space, or of the atoms of matter, as these philosophers have called them. Epicurus asserted a gravity or weight which forced these elementary particles to sink or fall; and this does not seem to differ much from Newton's Attraction, which I accept. He also gave them a certain deviation from the straight line in their falling movement, although he had absurd fancies regarding the causes and consequences of it. This deviation agrees in some degree with the alteration from the falling in a straight line, which we deduce from the repulsion of the particles. Finally, the vortices which arose from the disturbed motion, is also a theory of Leucippus and Democritus, and it will be also found in our scheme. So many points of affinity with a system which constituted the real theory of all denial of God in antiquity do not, however, draw my system into community with its errors. Something true will always be found even in the most nonsensical opinions that have ever obtained the consent of men. A false principle, or a couple of unconsidered conjunctive propositions, lead men away from the high footpath of truth by unnoticed by-paths into the abyss. Notwithstanding the similarity indicated, there yet remains an essential difference between the ancient cosmogony and that which I present, so that the very opposite consequences are to be drawn from mine.

The teachers of the mechanical production of the structure of the world referred to, derive all the order which may be perceived in it from mere chance which made the atoms to meet in such a happy concourse that they constituted a well-ordered whole. Epicurus had the hardihood to maintain that the atoms diverged from their straight motion without a cause, in order that they might encounter one another. All these theorizers pushed this absurdity so far that they even assigned the origin of all animated creatures to this blind concourse, and actually derived reason from the irrational. In my system, on the contrary, I find matter bound to certain necessary laws. Out of its universal dissolution and dissipation I see a beautiful and orderly whole quite naturally developing itself. This does not take place by accident, or of chance; but it is perceived that natural qualities necessarily bring it about. And are we not thereby moved to ask, why matter must just have had laws which aim at order and conformity? Was it possible that many things, each of which has its own nature independent of the others, should determine each other of themselves just in such a way that a well-ordered whole should arise therefrom; and if they do this, is it not an undeniable proof of the community of their origin at first, which must have been a universal Supreme Intelligence, in which the natures of things were devised for common combined purposes?

Matter, which is the primitive constituent of all things, is therefore bound to certain laws, and when it is freely abandoned to these laws it must necessarily bring forth beautiful combinations. It has no freedom to deviate from this perfect plan. Since it is thus subject to a supremely wise purpose, it must necessarily have been put into such harmonious relationships by a First Cause ruling over it; and *there is a God, just because nature even in chaos cannot proceed otherwise than regularly and according to order.*

I have such a good opinion of the honest judgment of those who will do my Essay the honour of examining it, that I am certain that the reasons now adduced, if they do not remove all anxiety about the injurious consequences of my system, will at least put the purity of my intention beyond doubt. If there are, nevertheless, ill-disposed zealots who regard it as a duty worthy of their sacred calling to attach prejudicial interpretations to innocent opinions, I am persuaded that their judgment will have the opposite effect of their intention with reasonable men. Moreover, I am not to be deprived of the right which Descartes has always enjoyed with just judges since he ventured to explain the formation of the heavenly bodies by merely natural laws. I will therefore quote the Authors of the *Universal History*, when they say: "However, we cannot but think the essay of that philosopher who endeavoured to account for the formation of the world in a certain time from a rude matter, by the sole continuation of a motion once impressed, and reduced to a few simple and general laws; or of others, *who have since attempted the same, with more applause, from the original properties of matter, with which it was endued at its creation*, is so far from being criminal or injurious to God, as some have imagined, that it is rather giving a more sublime idea of His infinite wisdom."[1]

I have tried to remove the objections which seemed to threaten my positions from the side of religion. There are others not less forcible that arise in regard to the subject itself. Thus it will be said, that although it is true that God has put a secret art into the forces of nature so as to enable it to fashion itself out of chaos into a perfect world system, yet will the intelligence of man, so weak as it is in dealing with the commonest objects, be capable of investigating the hidden properties

[1] Part I. § 88. [This quotation is taken from the Introduction to the large English History of the World entitled, *An Universal History from the Earliest Account of Time to the Present:* compiled from Original Authors; and illustrated with Maps, Cuts, Notes, Chronological and other Tables. London, 7 vols. 4°. 1736-44. Vol. I., p. 36 c. The Introduction quoted from deals with the Cosmogony or Creation of the World, and it gives an account of all the principal theories ancient and modern, as then understood. The quotation as given in the text is from the original work, but the italics run after Kant's rendering. 'That philosopher' is Descartes; the 'others' are Burnet and Whiston.—Tr.]

contained in so great an object? Such an undertaking would be equivalent to saying: '*Give me matter only, and I will construct a world out of it.*' Does not the weakness of your insight, which comes to grief on the pettiest objects daily presented to your senses and in your neighbourhood, teach you that it is vain to try to discover the immeasurable, and what took place in nature before there was yet a world? I annihilate this objection by clearly showing that of all the inquiries which can be raised in connection with the study of nature, this is the one in which we can most easily and most certainly reach the ultimate. Just as among all the problems of natural science none can be solved with more correctness and certainty than that of the true constitution of the universe as a whole, the laws of its movements, and the inner mechanism of the revolutions of all the planets—that department of science in which the Newtonian philosophy can furnish such views as are nowhere else to be met with; so I assert, that among all the objects of nature whose first cause is investigated, the origin of the system of the world and the generation of the heavenly bodies, together with the causes of their motions, is that which we may hope to see first thoroughly understood. The reason of this is easy to see. The heavenly bodies are round masses, and therefore have the simplest formation which a body whose origin is sought can possibly have. Their movements are likewise uncomplicated; they are nothing but a free continuation of an impulse once impressed, which, by being combined with the attraction of the body at its centre, becomes circular. Moreover, the space in which they move is empty; the intervals which separate them from each other are exceptionally large, and everything is thus disposed not only for undisturbed motion but also for distinct observation of it in the clearest way. It seems to me that we can here say with intelligent certainty and without audacity: '*Give me matter, and I will construct a world out of it!*' *i.e.* give me matter and I will show you how a world shall arise out of it. For if we have matter existing endowed with an essential force of attraction, it is not difficult to determine those causes which may have contributed to the arrangement of the system of the world as a whole. We know what is required that a body shall take a spherical figure; and we understand what is required in order that spheres, as orbs moving freely, may assume a circular movement around the centre to which they are drawn. The position of their orbits, in relation to each other, agreement in the direction of their motions, the eccentricity of their paths, may all be referred to the simplest mechanical causes; and we may confidently hope to discover them because they can be reduced to the easiest and clearest principles. But can we boast of the same progress even regarding the lowest plant or an insect? Are we in a position to say: '*Give me matter, and I will show you how a caterpillar can be produced*'? Are we not arrested here at the first step, from ignorance of the real inner conditions of the object and the complication of the manifold constituents existing in it? It should not therefore cause astonishment if I presume to say that the formation of all the heavenly bodies, the cause of their movements, and, in short, the origin of the whole present constitution of the universe, will become intelligible before the production of a single herb or a caterpillar by mechanical causes, will become distinctly and completely understood.

These are the grounds on which I base my confidence that the physical part of universal science may hope in the future to reach the same perfection as that to which Newton has raised the mathematical half of it. Next to the laws by which the universe subsists in the constitution in which it is found, there are perhaps no other laws in the whole sphere of natural science that are capable of such exact mathematical determination as those in accordance with which the system arose. And undoubtedly the hand of a skilful mathematician may here reap no unfruitful fields.

Having thus taken occasion to recommend the subject here considered to a favourable reception, I may now be allowed to explain briefly the manner in which I have treated it. The *First Part* deals with a new system of the universe generally. Mr Wright of Durham, whose treatise I have come to know from the Hamburg publication entitled the *Freie Urteile*, of 1751, first suggested ideas that led me to regard the fixed stars not as a mere swarm scattered without visible order, but as a system which has the greatest resemblance with that of the planets; so that just as the planets in their system are found very nearly in a common plane, the fixed stars are also related in their positions, as nearly as possible, to a certain plane which must be conceived as drawn through the whole heavens, and by their being very closely massed in it they present that streak of light which is called the Milky Way. I have become persuaded that because this zone, illuminated by innumerable suns, has very exactly the form of a great circle, our sun must be situated very near this great plane. In exploring the causes of this arrangement, I have found the view to be very probable that the so-called fixed stars may really be slowly moving, wandering stars of a higher order. In confirmation of what will be found regarding this thought in its proper place, I will here quote only a passage from a paper of Mr Bradley on the motion of the fixed stars: "If a judgment may be formed with regard to this matter, from the result of the comparison of our best modern observations with such as were formerly made with any tolerable degree of exactness, there appears to have been a real change in the position of some of the fixed stars, with respect to each other, and such as seems independent of any motion in our own system, and can only be referred to some motion in the stars themselves. Arcturus affords a strong proof of this: for if its present declination be compared with its place as determined either by Tycho or Flamsteed, the difference will be found to be much greater than what can be suspected to arise from the uncertainty of their observations. It is reasonable to expect that other instances of the like kind must also occur among the great number of the visible stars, because their relative positions may be altered by various means. For if our own solar system be conceived to change its place with respect to absolute space, this might, in process of time, occasion an apparent change in the angular distances of the fixed stars; and in such a case, the places of the nearest stars being more affected than of those that are very remote, their relative positions might seem to alter, though the stars themselves were really immovable. And on the other hand, if our own system be at rest and any of the stars really in motion, this might likewise vary their apparent positions; and the more so, the nearer they are to us, or the swifter their motions are, or the more proper the direction of the motion is to be rendered perceptible by us. Since then the relative places of the stars may be changed from such a variety of causes, considering that amazing distance at which it is certain that some of them are placed, it may require the observations of many ages to determine the laws of the apparent changes even of a single star. Much more difficult therefore must it be to settle the laws relating to all the most remarkable stars."[1]

I cannot exactly define the boundaries which lie between Mr Wright's system and my own; nor can I point out in what details I have merely imitated his sketch or have carried it out further. Nevertheless, I found afterwards valid reasons for considerably expanding it on one side. I considered the species of nebulous stars, of which De Maupertuis makes mention in his treatise *On the Figure of the Fixed Stars*,[2] which present the form of

[1] [*Philosophical Transactions*, Vol. XLV., for the year 1748. Pp. 39-41. London, 1750.]

[2] As I have not the treatise referred to at hand, I will here insert what bears upon the subject from a quotation taken from the *Ouvrages divers* de Msr. Maupertuis in the *Acta Eruditorum*, 1745. "Le premier phénomène est celui de ces *taches brillantes* du ciel, que l'on nomme *nébuleuses*, et qui ont été considérées comme des amas de petites étoiles. Mais les astronomes, à l'aide de meilleures lunettes, ne les ont vues que comme de grandes aires ovales, lumineuses, ou d'une lumière plus claire que le reste du ciel. Huygens en a rencontré d'abord une dans Orion; Halley, dans les *Philosophical Transactions*, signale six de ces nébulosités, dont la première est dans l'épée d'Orion; la deuxième dans le Sagittaire; la troisième dans le Centaure; la quatrième devant le pied droit d'Antinoüs; la cinquième dans Hercule, et la sixième dans la Ceinture d'Andromède. Cinq de ces taches ayant été observées avec un réflecteur de 8 pieds, il ne s'en est trouvé qu'une, la quatrième, qui puisse être prise pour un amas d'étoiles; les autres paraissent de grandes aires blanchâtres

more or less open ellipses; and I easily persuaded myself that these stars can be nothing else than a mass of many fixed stars. The regular constant roundness of these figures, taught me that an inconceivably numerous host of stars must be here arranged together and grouped around a common centre, because their free positions towards

et ne diffèrent entre elles qu'en ce que les unes sont plus rondes et les autres plus ovales. Il semble aussi que, dans la première, les petites étoiles qu'on découvre avec le télescope ne paraissent pas capables de causer sa blancheur. Halley a été frappé de ces phénomènes qu'il croit propres à éclaircir une chose qui parait difficile à entendre dans le livre de la Genèse, qui est que la lumière fut créée avant le Soleil. Durham les regarde comme des trous, à travers lesquels on découvre une région immense de lumière, et enfin le ciel empyrée. Il prétend avoir pu distinguer que les étoiles qu'on aperçoit dans quelques-unes sont beaucoup moins éloignées de nous que ces taches. M. de Maupertuis donne dans son Ouvrage un catalogue de ces nébuleuses d'après Hévélius. Il les considère comme de grandes masses de lumière, qui ont été aplaties par une puissante rotation. Si la matière dont elles sont formées possédait le même pouvoir éclairant que les étoiles, il faudrait que leur grosseur fût énorme par rapport à la leur, pour que, malgré leur éloignement beaucoup plus grand, que fait voir la diminution de leur lumière, on les voie au télescope avec grandeur et figure. Si on les suppose d'une grosseur égale à celle des étoiles, il faut que la matière qui les forme soit moins lumineuse et qu'elles soient infiniment plus proches de nous, pour que nous les puissions voir avec une grandeur sensible. Cela vaudrait donc la peine de chercher à déterminer leur parallaxe, dans le cas où elles en auraient une. Car ce n'est peut-être que par un trop petit nombre d'astres observés qu'on a désespéré de la parallaxe des autres. Les petites étoiles que l'on rencontre sur ces taches comme dans Orion (ou mieux dans celle du pied droit d'Antinoüs, qui apparait comme une étoile entourée d'une nébulosité), si elles sont proches de nous, seraient vues projetées sur le disque de ces astres; si elles le sont moins, nous voyons les étoiles à travers comme on les voit à travers les queues des comètes." [*Discours sur les différentes figures des astres* par M. de Maupertuis, Chap. VI., pp. 104-114. It has been thought better to quote the original than to re-translate the German translation.—Tr.]

each other would otherwise have presented irregular forms and not exact figures. I also perceived that they must be limited mainly to one plane in the system in which they are found united, because they do not exhibit circular but elliptical figures. And I further saw that, on account of their feeble light, they are removed to an inconceivable distance from us. What I have inferred from these analogies, is presented in the following treatise for the examination of the unprejudiced reader.

In the *Second Part*, which contains the most distinctive discussion in this treatise, I try to evolve the constitution of the universe out of the simplest state of nature. If I may venture to suggest a certain order to those who may be roused at the boldness of this undertaking, when they do me the honour to examine my thoughts, I would ask them first to read through the Eighth Chapter, which, I hope, will prepare them for a correct understanding and judgment of my work. Meanwhile, if I invite the kindly reader to examine my opinions, I am naturally anxious, seeing that hypotheses of this kind commonly do not stand in much better repute than philosophic dreams, lest it should prove a troublesome courtesy for a reader to resolve to give himself to a careful examination of histories of nature that have been thought out by another and patiently to follow the author through all the windings by which he compasses all the difficulties which encounter him—perhaps at the end, like the spectators of the London Market Crier, to laugh at his own credulity, as in Gellert's Fable of Hans Nord. Yet, I venture to promise, that if the reader will be persuaded, as I hope, by the prefixed preparatory chapter, to accompany me in this adventurous expedition through the physical world on the ground of such probable conjectures, he will not find in the course of the expedition so many crooked by-paths or insuperable obstacles as he perhaps apprehends at the outset.

In fact, I have with the greatest carefulness kept clear of all arbitrary hypotheses. After having resolved the world into the simplest chaos, I have applied no other forces than those of attraction and repulsion to the evolution of the great order of nature: two forces which are both equally certain, equally simple, and, at the same time, equally original and universal. They are both borrowed from the Natural Philosophy of Newton. The first is a law of nature, which is now established beyond doubt. The second, which is perhaps not demonstrated by the science of Newton with so much distinctness as the first, is accepted here only in that understanding of it which no one questions, namely, in connection with the finest dissolution of matter, as, for instance, in vapours. It is from these very simple principles that I have deduced the following system in an unfactitious manner, without working out any other consequences than those which must themselves command the attention of the reader.

Finally, I may be permitted to make a brief explanation regarding the validity and the presumed value of the propositions which will appear in the following theory, and by which I wish it to be tested by just judges. It is fair to judge an author by the stamp which he impresses on his wares; and, therefore, I hope that in the different parts of this treatise no more rigid vindication of my opinions will be demanded than what is in accordance with the degree of the validity which I assign to them myself. Speaking generally, the greatest mathematical precision and mathematical infallibility can never be required from a treatise of this kind. If the system is founded upon analogies and harmonies, which are in accordance with the rules of credibility and correct reasoning, it has satisfied all the requirements of its subject. I believe that I have reached this degree of thoroughness in some parts of this treatise: as in the theory of the system of the fixed stars, in the hypothesis of the condition of the nebulous stars, in the general scheme of the mechanical production of the structure of the world, in the theory of Saturn's ring, and in other points. Some of the details will produce somewhat less conviction; as, for example, the determination of the relations of eccentricity, the comparison of the masses of the planets, the manifold deviations of the comets, and some other propositions.

When, therefore, in the Seventh Chapter, allured by the fruitfulness of the system and the charm of the grandest and most wonderful object to which thought can be applied, although always guided by the thread of analogy and a rational credibility, I yet pursue with some boldness the consequences of the system as far as possible; and when I present to the imagination the infinitude of the whole creation, the formation of new worlds, the destruction of old worlds, and the boundless space of chaos, I hope that the attractive charm of the subject and the pleasure which is felt in discerning the harmony of a theory in its widest range, will win so much consideration that it will not be judged by the utmost geometrical rigour, which, moreover, is not in place in connection with such theoretical speculations. I crave the same fairness in dealing with the *Third Part.* Yet, there will be found in it something more than what is merely arbitrary, although always something less than the indubitable.

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FIRST PART.

SKETCH OF A SYSTEMATIC CONSTITUTION AMONG THE FIXED STARS,

LIKEWISE

OF THE PLURALITY OF SUCH STAR SYSTEMS.

"Look round our World; behold the chain of Love
Combining all below and all above."—POPE.

INTRODUCTION.

BRIEF SKETCH OF THE MOST NECESSARY PRINCIPLES OF NEWTON'S NATURAL PHILOSOPHY, WHICH ARE REQUIRED FOR THE UNDERSTANDING OF WHAT FOLLOWS.[1]

SIX planets, of which three have companions—Mercury, Venus, the Earth with its moon, Mars, Jupiter with four satellites, and Saturn with five—describe circles around

[1] This short introduction, which may perhaps be unnecessary for most readers, I have thought it desirable to draw up for those who may not be sufficiently acquainted with Newton's principles, in order that it may prepare them to understand the following theory. [It need hardly be said that Kant here gives an account of the elements of the Solar System, only in so far as known at the time when he wrote (1755). The great discoveries made since then have to be kept in mind, especially in their important bearing on the proof of his theory. The great planet Uranus was discovered by Sir W. Herschel in 1781, twenty-six years after the publication of Kant's essay. The first asteroid, or minor planet Ceres, was discovered by Piazzi of Palermo, on the first day of the nineteenth century, and some four hundred more have been discovered since. The still more remarkable discovery of Neptune, on the basis of the calculations of Adams and Leverrier, was made in 1846. Mr Hall of Washington discovered, on 11th and 17th August, 1877, that Mars has two moons.—Tr.]

the sun as the centre; and, along with the comets, which likewise revolve around the sun, coming to it from all sides and in very wide orbits, they constitute a system which is called the Solar System, or the Planetary World. The movement of all these bodies, since it is circular and returns into itself, presupposes two forces which are equally necessary in every theory of the system. The one is a Propulsive Force, whereby they would continue to move on in a straight direction at every point of their curved course, and would go off into the infinite did not another force constantly compel them to leave that direction and to move in a curved line, which has the sun as its centre. This second force, as is undoubtedly established by geometry, is always directed to the sun, and is, therefore, called the Falling Force, the Centripetal Force, or Gravitation.

If the orbits of the planets were exact circles, the very simplest analysis of the composition of curvilinear movements would show that a constant tendency to the centre would be required to produce them. But although the orbits of all the planets, as well as of the comets, are ellipses in whose common focus the sun is situated, yet the higher geometry, by the aid of Kepler's Analogy (according to which the radius vector, or the line drawn from the planet to the sun, always describes areas of the elliptical path, which are proportional to the time of movement), shows with infallible certainty that a force must incessantly impel the planet towards the centre of the sun during the whole of its revolution. This falling force, which rules through the whole extension of the planetary system and is directed to the sun, is thus an established phenomenon of nature. And just as certainly is the law demonstrated under the regulation of which this force extends from the centre of the system to the remote regions. It always decreases inversely, as the squares of the distances from the centre increase. This rule flows in the same infallible way from the time which the planets take at their various distances for their revolutions. These times, their periods of revolution, are always as the square root of the cubes of their mean distances from the sun; and from this it has been deduced that the force which impels these heavenly bodies to the centre around which they revolve, must diminish in the inverse ratio of the square of their distance.

This same law that rules the planets, in so far as they revolve around the sun, is also found in the smaller systems, namely, those constituted by the moons moving around their own planets. The times of their revolution are in like manner proportional to their distances, and establish the same relation of the falling force towards the planet as that to which the planet is subjected in its relation to the sun. All this is established beyond question by the most certain mathematics, and by means of indisputable observations. Thus arises the idea that this falling force is the very same impulse which is called gravity on the surface of the planet, and which, starting from the planet, gradually diminishes with the distances, according to the law indicated. This is seen from a comparison of the quantum of gravity upon the surface of the earth with the force that drives the moon towards the centre of its orbit, which shows the same relation as attraction does in the whole universe; that is to say, the gravity or weight is in the inverse ratio of the square of the distance. This is the reason why the central force, so often mentioned, is also called gravity.

And, moreover, it is in the highest degree probable that if an action takes place only in the presence of a certain body and in the proportion of its proximity, and if the direction of it is also to be referred most exactly to this body, it must be believed that this body is in some way or other the cause of that action; and hence it is held that there is sufficient reason for ascribing this universal falling of the planets towards the sun to a Force of Attraction in the sun, and to attribute this same power of attraction to all the heavenly bodies.

When a body, therefore, is freely abandoned to this influence, which impels it to sink towards the sun or to a certain planet, it will fall to it in a constantly accelerated motion, and at last will unite with its mass. But if it has obtained an impetus sideways, and if this is not so powerful as to form an exact equilibrium with the falling force, it will fall in a curved movement towards the central body. And if the impulsion which has been impressed upon it, has been at least strong enough before it comes in contact with the surface of the central body to remove it from the perpendicular line by half the diameter of the body in the centre, it will not reach its surface; but after it has swung itself close round it, by the velocity acquired in falling, it will again raise itself as high as it had fallen, then to continue its revolution in a constant circular movement round it.

The difference between the orbits of the comets and the planets, thus consists in the balancing of the lateral movement with the pressure which impels them to fall :

which two forces, the more they approach equality, make the orbit more like the circular figure; and the more unequal they are, the weaker the propulsive force is in relation to the central force, so much the more elongated will be the orbit. Or, as it is called, it is so much the more *eccentric*, because the heavenly body approaches the sun much nearer at one part of its path than at another.

As there is nothing in the whole of nature that is balanced with the utmost exactness, no planet has a wholly circular movement. But the comets diverge most therefrom; because the impulsion which has been impressed upon them laterally, has been least proportionated to the central force of their initial distance.

In this treatise I shall very frequently use the expression: *A Systematic Constitution of the Universe.* In order that no difficulty may be found in clearly understanding what is meant to be indicated by the phrase, I will shortly explain it. All the planets and comets which belong to our world, properly constitute a system by the fact that they revolve around a common central body. But I use this designation in a stricter sense, looking at the more exact relations which their combination with each other has made so regular and uniform. The orbits of the planets are related as nearly as possible to a common plane, which is that of the equator of the sun prolonged; and deviation from this rule is found only at the utmost limit of the system, where all movements gradually cease. When, therefore, a number of heavenly bodies which are arranged round a common centre, and move around it, have at the same time been so limited to a certain plane that they have freedom to diverge from it on both sides only as little as possible; when the divergence takes place gradually and only in those bodies which are furthest removed from the centre, and therefore have less participation in the relations indicated than the others: then I say that these bodies are found combined together in a *Systematic Constitution.*

FIRST PART.

OF THE SYSTEMATIC CONSTITUTION AMONG THE FIXED STARS.

The scientific theory of the Universal Constitution of the World has obtained no remarkable addition since the time of Huygens. At the present time nothing more is known than what was already known then, namely, that six planets with ten satellites, all performing the circle of their revolution almost in one plane, and the eternal comets which sweep out on all sides, constitute a system whose centre is the sun, towards which they all fall, around which they perform their movements, and by which they are all illuminated, heated, and vivified; finally, that the fixed stars are so many suns, centres of similar systems, in which everything may be arranged just as grandly and with as much order as in our system; and that the infinite space swarms with worlds, whose number and excellency have a relation to the immensity of their Creator.

The systematic arrangement which was found in the combination of the planets which move around their sun, seemed in the view of astronomers of that time to disappear in the multitude of the fixed stars; and it appeared as if the regulated relation which is found in the smaller solar system, did not rule among the members of the universe as a whole. The fixed stars exhibited no law by which their positions were bounded in relation to each other; and they were looked upon as filling all the heavens and the heaven of heavens without order and without intention. Since the curiosity of man set these limits to itself, he has done nothing further than from these facts to infer, and to admire, the greatness of Him who has revealed Himself in works so inconceivably great.

It was reserved for an Englishman, Mr Wright of Durham, to make a happy step with a remark which does not seem to have been used by himself for any very important purpose, and the useful application of which he has not sufficiently observed. He regarded the Fixed Stars not as a mere swarm scattered without order and without design, but found a systematic constitution in the whole universe and a universal relation of these stars to the ground-plan of the regions of space which they occupy. We would attempt to improve the thought which he thus indicated, and to give to it that modification by which it may become fruitful in important consequences whose complete verification is reserved for future times.

Whoever turns his eye to the starry heavens on a clear night, will perceive that streak or band of light which on account of the multitude of stars that are accumulated there more than elsewhere, and by their getting perceptibly lost in the great distance, presents a uniform light which has been designated by the name *Milky Way.* It is astonishing that the observers of the heavens have not long since been moved by the character of this perceptibly distinctive zone in the heavens, to deduce from it special determinations regarding the position and distribution of the fixed stars. For it is seen to occupy the direction of a great circle, and to pass in uninterrupted connection round the whole heavens: two conditions which imply such a precise destination and present marks so perceptibly different from the indefiniteness of chance, that attentive astronomers ought to have been thereby led, as a matter of course, to seek carefully for the explanation of such a phenomenon.

As the stars are not placed on the apparent hollow sphere of the heavens, and as some are more distant than others from our point of view and are lost in the depths of the heavens, it follows from this, that at the distances at which they are situated away from us, one behind the other, they are not indifferently scattered on all sides, but must have a predominant relation to a certain plane which passes through our point of view and to which they are arranged so as to be found as near it as possible. This relation is such an undoubted phenomenon that even the other stars which are not included in the whitish streak, are yet seen to be more accumulated and closer the nearer their places are to the circle of the Milky Way; so that of the two thousand stars which are perceived by the naked eye, the greatest part of them are found in a not very broad zone whose centre is occupied by the Milky Way.

If we now imagine a plane drawn through the starry heavens and produced indefinitely, and suppose that all the fixed stars and systems have a general relation in their places to this plane so as to be found nearer to it than to other regions, then the eye which is situated in this plane when it looks out to the field of the stars, will perceive on the spherical concavity of the firmament the densest accumulation of stars in the direction of such a plane under the form of a zone illuminated by varied light. This streak of light will advance as a luminous band in the direction of a great circle, because the position of the spectator is in the plane itself. This zone will swarm with stars which, on account of the indistinguishable minuteness of their clear points that cannot be severally discerned and their apparent denseness, will present a uniformly whitish glimmer,—in a word, a Milky Way. The rest of the heavenly host whose relation to the plane described gradually diminishes, or which are situated nearer the position of the spectator, are more scattered, although they are seen to be massed relatively to this same plane. Finally, it follows from all this that our solar world, seeing that this system of the fixed stars is seen from it in the direction of a great circle, is situated in the same great plane and constitutes a system along with the other stars.

In order to penetrate better into the nature of the universal connection which rules in the universe, we will try to discover the cause that has made the positions of the fixed stars come to be in relation to a common plane.

The sun is not limited in the range of its attractive force to the narrow domain of the planetary system. According to all appearance the force of attraction extends *ad infinitum*. The comets, which pass very far beyond the orbit of Saturn, are compelled by the attraction of the sun to return again, and to move in orbits. Although, therefore, it is more in accordance with the nature of a force which seems to be incorporated in the essence of matter, to be unlimited, and it is also actually recognized to be so by those who accept Newton's principles, yet we would only have it granted that this attraction of the sun extends approximatively to the nearest fixed star; also that the fixed stars, as being so many suns, exercise an action around them in a similar range; and, consequently, that the whole host of them are striving to approach each other through their mutual attraction. Thus all the systems of the universe are found so constituted by their mutual approach, which is incessant and is hindered by nothing, that they will fall together sooner or later into one mass, unless this ruin is prevented by the action of the centrifugal forces, as in the globes of our planetary system. These forces, by deflecting the heavenly bodies from falling in a straight line, bring about, when combined with the forces of attraction, their perpetual revolutions, and thereby the structure of the creation is secured from destruction and is adapted for an endless duration.

Thus all the suns of the firmament have movements of revolution, either round one universal centre or round many centres. But we may here apply the analogy which is observed in the revolutions of our Solar System, namely, that the same cause that has communicated to the planets the centrifugal force, in virtue of which they perform their revolutions, has also so directed their orbits that they are all related to one plane. And so also the cause, whatever it may be, which has given the power of revolving to the suns of the upper world, as so many wandering stars of a higher order of worlds, has likewise brought their orbits as much as possible into one plane, and has striven to limit the deviations from it.

Following out this idea, the System of the Fixed Stars may be viewed as represented in some measure by the System of the Planets, if the latter be regarded as indefinitely enlarged. If instead of the six planets with their ten companions, we suppose there to be as many thousands of them; if the twenty-eight or thirty comets which have been observed be multiplied a hundred or a thousand times, and if we suppose these same bodies to be self-luminous, then the eye of the spectator looking at them from the earth would see before it just the very appearance of what is presented to it by the fixed stars of the Milky Way. For these supposed planets, by their proximity to the common plane of their relation, being situated with our earth in the same plane, would present to us a zone densely illuminated by innumerable stars, and its direction would be that of a great circle of the celestial sphere. This streak of light would be seen everywhere thickly sown with stars, although, according to the hypothesis, they are wandering stars and consequently not fixed to one place; for by their displacement there would always be found stars enough on one side, although others had changed from that position.

The breadth of this luminous zone, which represents a sort of zodiac, will be determined by the different degrees of the deviation of the said wandering stars from the plane of their relation, and by the inclination of their orbits to this plane; and as most of them are near this plane, their number will appear more scattered according to the degree of their distance from it. But the comets which occupy all the regions of space without distinction, will cover the field of the heavens on both sides.

The form of the starry heavens is therefore due to no other cause than such a systematic constitution on the great scale as our planetary world has on the small—all the suns constituting a system whose universal relative plane is the Milky Way. Those suns which are least closely related to this plane, will be seen at the side of it; but on that account they are less accumulated, and are much more scattered and fewer in number. They are, so to speak, the comets among the suns.

This new theory attributes to the suns an advancing movement; yet everybody regards them as unmoved, and as having been fixed from the beginning to their places. The designation of them as 'Fixed' Stars, which they have received from that view of them, seems to be established and put beyond doubt by the observation of all the centuries. This difficulty raises an objection which would annihilate the theory here advanced, were it well founded. But in all probability this want of movement is merely apparent. It is either only excessively slow, arising from the great distance from the common centre around which the stars revolve, or it is due to mere imperceptibility, owing to their distance from the place of observation. Let us estimate the probability of this conception by calculating the motion which a fixed star near our sun would have, if we supposed our sun to be the centre of its orbit. If, following Huygens, its distance is assumed to be more than 21,000 times greater than the distance of the sun from the earth, then according to the established law of the periods of revolution—which are in the ratio of the square root of the cube of the distances from the centre—the time which such a star would require to revolve once round the sun would be more than a million and a half years; and this would only produce a displacement of its position by one degree in four thousand years. Now, as there are perhaps very few fixed stars so near the sun as Huygens has conjectured Sirius to be, as the distance of the rest of the heavenly host perhaps immensely exceeds that of Sirius, and would therefore require incomparably longer time for such a periodic revolution; and, moreover, as it is very probable that the movement of the suns of the starry heavens goes round a common centre, whose distance is incomparably great, so that the progression of the stars may therefore be exceedingly slow, it may be inferred with probability from this, that all the time that has passed since men began to make observations on the heavens is perhaps not yet sufficient to make perceptible the alteration which has been produced in their positions. We need not, however, give up the hope yet of discovering even this alteration, in the course of time. Subtle and careful observers, and a comparison of observations taken at a great distance from each other, will be required for it. These observations must be directed especially to the stars of the Milky Way,[1] which is the main plane of all motion. Mr Bradley has observed almost imperceptible displacements of the stars. The ancients have noticed stars in certain places of the heavens, and we see new ones in others. Who knows but that these are just the former, which have only changed their place? The excellence of our

[1] Likewise to those clusters of stars, of which there are many found together in a small space, as, for example, the Pleiades, which perhaps make up a small system by themselves in the greater system.

instruments and the perfection of astronomy, give us well-founded hopes for the discovery of such peculiar and remarkable things.[1] The credibility of the fact itself, in accordance with the principles of nature and analogy which well support this hope, is such that they may stimulate the attention of the explorer of nature so as to bring about its realization.

The Milky Way is, so to speak, the zodiac of new stars which alternately show themselves and disappear, almost only in that region of the heavens. If this alteration of their visibility arises from their periodical removal and approach to us, then it appears from the systematic constitution of the stars here indicated, that such a phenomenon must be seen for the most part only in the region of the Milky Way. For as there are stars which revolve in very elongated orbits around other fixed stars like satellites around their planets, analogy with our planetary world, in which only those heavenly bodies that are near the common plane of the movements have companions revolving round them, demands that those stars only which are in the Milky Way will also have suns revolving round them.

I come now to that part of my theory which gives it its greatest charm, by the sublime idea which it presents of the plan of the creation. The train of thought which has led me to it is short and natural; it consists of the following ideas. If a system of fixed stars which are related in their positions to a common plane, as we have

[1] De la Hire, in the *Mémoires* of the Paris Academy of the year 1693, remarks that from his own observations, as well as from comparison of them with those of Ricciolus, he has perceived a marked alteration in the positions of the stars of the Pleiades.

delineated the Milky Way to be, be so far removed from us that the individual stars of which it consists are no longer sensibly distinguishable even by the telescope; if its distance has the same ratio to the distance of the stars of the Milky Way as that of the latter has to the distance of the sun; in short, if such a world of fixed stars is beheld at such an immense distance from the eye of the spectator situated outside of it, then this world will appear under a small angle as a patch of space whose figure will be circular if its plane is presented directly to the eye, and elliptical if it is seen from the side or obliquely. The feebleness of its light, its figure, and the apparent size of its diameter will clearly distinguish such a phenomenon when it is presented, from all the stars that are seen single.

We do not need to look long for this phenomenon among the observations of the astronomers. It has been distinctly perceived by different observers. They have been astonished at its strangeness; and it has given occasion for conjectures, sometimes to strange hypotheses, and at other times to probable conceptions which, however, were just as groundless as the former. It is the 'nebulous' stars which we refer to, or rather a species of them, which M. de Maupertuis thus describes: 'They are,' he says, 'small luminous patches, only a little more brilliant than the dark background of the heavens; they are presented in all quarters; they present the figure of ellipses more or less open; and their light is much feebler than that of any other object we can perceive in the heavens.'[1]

The author of the *Astro-Theology* imagined that they

[1] *Discours sur la Figure des Astres.* Paris, 1742.

were openings in the firmament through which he believed he saw the Empyrean.[1] A philosopher of more enlightened views, M. de Maupertuis, already referred to, in view of their figure and perceptible diameter, holds them to be heavenly bodies of astonishing magnitude which, on account of their great flattening, caused by the rotatory impulse, present elliptical forms when seen obliquely.

Any one will be easily convinced that this latter explanation is likewise untenable. As these nebulous stars must undoubtedly be removed at least as far from us as the other fixed stars, it is not only their magnitude which would be so astonishing—seeing that it would necessarily exceed that of the largest stars many thousand times—but it would be strangest of all that, being self-luminous bodies and suns, they should still with this extraordinary magnitude show the dullest and feeblest light.

It is far more natural and conceivable to regard them as being not such enormous single stars but systems of many stars, whose distance presents them in such a narrow space that the light which is individually imperceptible from each of them, reaches us, on account of their immense multitude, in a uniform pale glimmer. Their analogy with the stellar system in which we find ourselves, their shape, which is just what it ought to be according to our theory, the feebleness of their light which demands a presupposed infinite distance: all this is in perfect harmony with the view that these elliptical figures are just universes and, so to speak, Milky Ways, like those whose constitution we have just unfolded. And if conjectures, with which analogy and

[1] [*Astro-Theology, or a Demonstration of the Being and Attributes of God from a Survey of the Heavens*, by W. Derham. London, 1714.]

observation perfectly agree in supporting each other, have the same value as formal proofs, then the certainty of these systems must be regarded as established.

The attention of the observers of the heavens, has thus motives enough for occupying itself with this subject. The fixed stars, as we know, are all related to a common plane and thereby form a co-ordinated whole, which is a World of worlds. We see that at immense distances there are more of such star-systems, and that the creation in all the infinite extent of its vastness is everywhere systematic and related in all its members.

It might further be conjectured that these higher universes are not without relation to one another, and that by this mutual relationship they constitute again a still more immense system. In fact, we see that the elliptical figures of these species of nebulous stars, as represented by M. de Maupertuis, have a very near relation to the plane of the Milky Way. Here a wide field is open for discovery, for which observation must give the key. The Nebulous Stars, properly so called, and those about which there is still dispute as to whether they should be so designated, must be examined and tested under the guidance of this theory. When the parts of nature are considered according to their design and a discovered plan, there emerge certain properties in it which are otherwise overlooked and which remain concealed when observation is scattered without guidance over all sorts of objects.

The theory which we have expounded opens up to us a view into the infinite field of creation, and furnishes an idea of the work of God which is in accordance with the infinity of the great Builder of the universe. If the grandeur of a planetary world in which the earth, as a grain of sand, is scarcely perceived, fills the understanding with wonder; with what astonishment are we transported when we behold the infinite multitude of worlds and systems which fill the extension of the Milky Way! But how is this astonishment increased, when we become aware of the fact that all these immense orders of star-worlds again form but one of a number whose termination we do not know, and which perhaps, like the former, is a system inconceivably vast—and yet again but one member in a new combination of numbers! We see the first members of a progressive relationship of worlds and systems; and the first part of this infinite progression enables us already to recognize what must be conjectured of the whole. There is here no end but an abyss of a real immensity, in presence of which all the capability of human conception sinks exhausted, although it is supported by the aid of the science of number. The Wisdom, the Goodness, the Power which have been revealed is infinite; and in the very same proportion are they fruitful and active. The plan of their revelation must therefore, like themselves, be infinite and without bounds.

But it is not only in the great system that important discoveries are to be made which will enlarge the conception that may be formed of the greatness of the creation. In the smaller system there is not less still undiscovered; and even in our Solar world we see the members of a system enormously distant from each other, and between which the intervening parts have not yet been discovered. Between Saturn, the outermost of the planets which we know, and the least eccentric comet which comes to us from a distance perhaps ten times more remote, may there not be another planet whose movement may approach nearer that of the comets than Saturn? And may there not be still others which, by an approximation of their determinations through a series of gradations, transform the planets gradually into comets, and connect the latter with the former?

The law according to which the eccentricity of the orbits of the planets are in the inverse ratio of their distance from the sun, supports this conjecture. The eccentricity in the movements of the planets, increases with their distance from the sun; and the more remote planets thus come nearer the definition of comets. It may therefore be supposed that there are other planets beyond Saturn which are still more eccentric in their orbits, and thereby have nearer affinity to comets, so that through a continuous gradation the planets finally become comets. The eccentricity in the case of Venus is $\frac{1}{126}$ of the semi-axis of its elliptical orbit; in the case of the Earth it is $\frac{1}{58}$; in the case of Jupiter $\frac{1}{28}$; in the case of Saturn $\frac{1}{17}$ of their respective semi-axes. The eccentricity therefore evidently increases with the distances. It is true that Mercury and Mars form exceptions to this law, on account of their much greater eccentricity than their actual distance from the sun would give; but we shall learn in the sequel that the same causes which explain why some planets obtained a smaller mass when they were formed, account for the deficiency of the impulsion required for a circular orbit, and consequently have produced their eccentricity; and in both respects this has left them incomplete.

Is it therefore not probable that the decrease of the eccentricity of the heavenly bodies situated next beyond Saturn, may be perhaps just as gradual as in the case of those within its orbit; and that the planets are brought into relation with the race of comets by so much the less sudden deviations? For it is certain that it is just this eccentricity that makes the essential difference between the comets and planets; and the tails and vapour heads of the comets are merely the effect of it. And in like manner it is certain that the cause, whatever it may have been, which has communicated their circular movements to the heavenly bodies, has not only been too weak at these greater distances to equalize the rotatory impulse with the force of attraction, and has thereby made the movements eccentric, but it has also on that account not been powerful enough to bring the orbits of these bodies into a common plane with that in which the inferior bodies move, and this has given occasion to the comets diverging in all directions.

According to this conjecture we may cherish the hope that new planets will perhaps yet be discovered beyond Saturn, and that these will be found to be more eccentric in their orbit than Saturn, and therefore nearer the character of comets. But for the same reason they would be perceptible only for a short time, namely, during the period of their perihelion, which circumstance, together with the slight degree of their approach to us and the feebleness of their light, has hitherto prevented the discovery of them, and will make their discovery difficult even in the future. The last planet and first comet might, if it so pleased, be styled the one whose eccentricity would be so great that in its perihelion it intersected the orbit of the planet nearest it—perhaps that of Saturn.

SECOND PART.

OF THE FIRST STATE OF NATURE, THE FORMATION OF THE HEAVENLY BODIES, THE CAUSES OF THEIR MOTIONS AND THEIR SYSTEMATIC CONNECTION, BOTH IN THE PLANETARY SYSTEM IN PARTICULAR AND IN THE WHOLE OF CREATION.

"See plastic nature working to this end,
The single atoms each to other tend,
Attract, attracted to, the next in place
Form'd and impell'd its neighbour to embrace.
See matter next, with various life endued,
Press to one center still, the gen'ral Good."

POPE.

FIRST CHAPTER.

OF THE ORIGIN OF THE STRUCTURE OF THE WORLD OF THE PLANETS GENERALLY AND THE CAUSES OF THEIR MOTIONS.

THE examination of the structure of the world, in regard to the mutual relations which its parts have to one another and by which they indicate the cause from which they sprang, shows that two views may be taken which are both equally probable and admissible. When, on the one hand, it is considered that the six planets with their nine satellites, which describe orbits around the sun as their centre, all move in one direction, that, namely, towards which the sun itself turns and which governs all their revolutions by the force of attraction; that their orbits do not diverge from a certain common plane, namely, that of the prolonged equatorial plane of the sun; and that in the case of the most distant heavenly bodies belonging to the Solar world where the common cause of motion *ex hypothesi* has not been so powerful as in the neighbourhood of the centre, deviations from the exactness of these determinations have taken place which have a relation sufficiently explained by the want of the impressed motion: when, I say, account is taken of all this connection, we shall be induced to believe that a cause, whatever it may be, has exercised an influence throughout the whole extent of the system, and that the accordance in the direction and position of the orbits of the planets is a consequence of the agreement which they must all have had with that material cause by which they have been put into motion.

On the other hand, if we consider the space in which the planets of our system revolve, it is found to be entirely empty[1] and bereft of all matter that could cause a community of influence on these heavenly bodies, or could bring about an accordance in their movements. This circumstance is established with perfect certainty, and, if possible, even surpasses the former in probability. Newton moved by this reason could allow no material cause which, by its extension through the space of the planetary system, could maintain the community of their movements. He asserted that the immediate hand of God had instituted this arrangement without the intervention of the forces of nature.

Impartially weighing these views, it appears that the reasons on the two sides are equally strong, and that both of them are to be regarded as equally claiming complete certainty. But it is just as clear that there must be a conception in which these several grounds, which apparently conflict with each other, may and can be combined, and that the true system is to be sought in this conception. We shall indicate it in a few words.

[1] I do not examine here the question whether this space can be called empty in the strictest sense of the term. For it is enough to remark here that any matter that might be met with in this space, is much too powerless to be able to exercise any influence with respect to the moving masses that are here in question.

In the present constitution of space, in which the globes of the whole planetary world revolve, there exists no material cause which could impress or direct their movements. This space is completely empty, or, at least, as good as empty; it must therefore have formerly been in another condition, and filled with enough of potential matter capable of transmitting motion to all the heavenly bodies found in it and bringing them into accordance with its own motion, so as to make them all concordant with each other. And after attraction had cleaned the said spaces and gathered all the scattered matter into particular masses, the planets must then have continued their revolutions freely and unaltered, in a non-resistant space, with the motion once impressed upon them. The reasons adduced for the probability of the first view absolutely desiderate this conception; and since the two cases are such that there is no third position possible between them, this view may be regarded with such approval as raises it above the semblance of an hypothesis. If we cared to carry it out in further detail, a series of successively deduced inferences, according to the mathematical method, could be advanced with all the parade that the method brings with it, and with even greater semblance than is wont to accompany their introduction in physical subjects, so as finally to reach the scheme which I would present regarding the origin of the universe. But I prefer to present my views in the form of an hypothesis, and to leave it to the intelligence of the reader to test their value rather than bring their validity into suspicion by the appearance of a surreptitious demonstration, lest, while winning the ignorant, I should lose the approval of those who really know the subject.

I assume that all the material of which the globes belonging to our solar system—all the planets and comets—consist, at the beginning of all things was decomposed into its primary elements, and filled the whole space of the universe in which the bodies formed out of it now revolve. This state of nature, when viewed in and by itself without any reference to a system, seems to be the very simplest that can follow upon nothing. At that time nothing had yet been formed. The construction of heavenly bodies at a distance from each other, their distances regulated by their attraction, their form arising out of the equilibrium of their collected matter, exhibit a later state. The state of nature which immediately bordered on the creation was as crude, as unformed, as possible. But even in the essential properties of the elements that constituted this chaos, there could be traced the mark of that perfection which they have derived from their origin, their essential character being a consequence of the eternal idea of the Divine Intelligence. The simplest and most general properties which seem to be struck out without design, the matter which appears to be merely passive and wanting form and arrangement, has in its simplest state a tendency to fashion itself by a natural evolution into a more perfect constitution. But the variety in the kinds of elements, is what chiefly contributes to the stirring of nature and to the formative modification of chaos, as it is by it that the repose which would prevail in a universal equality among the scattered elements is done away, so that the chaos begins to take form at the points where the more strongly attracting particles are. The kinds of this elementary matter are undoubtedly infinitely different, in accordance with the immensity which nature shows on all sides. Those elements, which are of greater specific density and force of attraction, and which of themselves occupy less room and are also rarer, would therefore be more scattered than the lighter kinds when the material of the world was equally diffused in space. Elements of a thousand times greater specific gravity, would therefore be thousands or even millions of times more scattered than those that are lighter in that proportion. And as these gradations must be thought to be as infinite as possible, there may be material particles of a kind which exceed those of another in density in the same proportion as a globe described with the radius of the planetary system does another which has only the thousandth part of a line in diameter; and thus these kinds of scattered elements would be separated from each other by a distance as great as those globes themselves.

In a region of space filled in this manner, a universal repose could last only a moment. The elements have essential forces with which to put each other in motion, and thus are themselves a source of life. Matter immediately begins to strive to fashion itself. The scattered elements of a denser kind, by means of their attraction, gather from a sphere around them all the matter of less specific gravity; again, these elements themselves, together with the material which they have united with them, collect in those points where the particles of a still denser kind are found; these in like manner join still denser particles, and so on. If we follow in imagination this process by which nature fashions itself into form through the whole extent of chaos, we easily perceive that all the results of the process would consist in the formation of diverse masses which, when their formation was complete, would by the equality of their attraction be at rest and be for ever unmoved.

But nature has other forces in store, which are especially exerted when matter is decomposed into fine particles. They are those forces by which these particles repel each other, and which, by their conflict with attraction, bring forth that movement which is, as it were, the lasting life of nature. This force of repulsion is manifested in the elasticity of vapours, the effluences of strong smelling bodies, and the diffusion of all spirituous matters. This force is an incontestable phenomenon of matter. It is by it that the elements, which may be falling to the point attracting them, are turned sideways promiscuously from their movement in a straight line; and their perpendicular fall thereby issues in circular movements, which encompass the centre towards which they were falling. In order to make the formation of the world more distinctly conceivable, we will limit our view by withdrawing it from the infinite universe of nature and directing it to a particular system, as the one which belongs to our sun. Having considered the generation of this system, we shall be able to advance to a similar consideration of the origin of the greater world-systems, and thus to embrace the infinitude of the whole creation in one conception.

From what has been said, it will appear that if a point is situated in a very large space where the attraction of the elements there situated acts more strongly than elsewhere, then the matter of the elementary particles scattered throughout the whole region will fall to that point. The first effect of this general fall is the formation of a body at this centre of attraction which, so to speak, grows from an infinitely small nucleus by rapid strides; and in the proportion in which this mass increases, it also draws with greater force the surrounding particles to unite with it. When the mass of this central body has grown so great that the velocity with which it draws the particles to itself from great distances, is bent sideways by the feeble degrees of repulsion with which they impede each other, and when it issues in lateral movements which are capable by means of the centrifugal force of encompassing the central body in an orbit, then there are produced whirls or vortices of particles, each of which by itself describes a curved line by the composition of the attracting force and the force of revolution that has been bent sideways. These kinds of orbits all intersect each other, for which their great dispersion in this space gives place. Yet these movements are in many ways in conflict with each other, and they naturally tend to bring one another to a uniformity, that is, into a state in which one movement is as little obstructive to the other as possible. This happens in two ways: first, by the particles limiting each other's movement till they all advance in one direction; and secondly, in this way, that the particles limit their vertical movements in virtue of which they are approaching the centre of attraction, till they all moving horizontally, *i.e.* in parallel circles round the sun as their centre, no longer intersect each other, and by the centrifugal force becoming equal with the falling force they keep themselves constantly in free circular orbits at the distance at which they move. The result, finally, is that only those particles continue to move in this region of space which have acquired by their fall a velocity, and through the resistance of the other particles a direction, by which they can continue to maintain a *free circular movement.* In this state, when all the particles are moving in one direction and in parallel circles, *i.e.* in free circular movements carried on by the acquired propulsive forces around the central body, the conflict and the concourse of the elements is annulled, and everything is then in the state of the least reciprocal action. This state is the natural consequence which always ensues in the case of matter involved in conflicting movements. It is therefore clear that a great number of the scattered multitude of particles must attain to such exact determinate conditions through the resistance by which they seek to bring each other to this state; although a much greater multitude of them do not reach it and only serve to increase the mass of the central body into which they fall, as they cannot maintain themselves freely at the distance at which they are moving, but cross the circles of the nearer particles, and, finally, by their resistance lose all motion. This body in the centre of attraction which, in consequence of all this, has become the chief part of the planetary system by the mass of its collected matter, is the sun, although it has not yet that glow of flame which bursts out on its surface after its formation has become entirely complete.

It is further to be observed, that all the elements of nature, when fashioning itself, thus move, as has been shown, in a direction round the centre of the sun; and hence in these revolutions, which are directed to a single region and which are performed as it were upon a common axis, the rotation of the fine matter cannot proceed in this way. Because, according to the laws of centrifugal motion, all the revolutions must intersect the centre of attraction with the plane of their orbits; but of all these orbits round a common axis that move in one direction, there is only one which cuts through the centre of the sun. Hence all the matter on both sides of this imaginary axis hurries to that circle which passes through the rotation of the axis in the centre of the common attraction, which circle is the plane of the reference of all the revolving elements: around which plane they accumulate as much as possible, and contrariwise leave the regions at a distance from this plane empty. For those elements which cannot come so near this plane to which they are all pressing, will not be able to continue to maintain themselves in the places where they are moving, but, impinging on the elements floating around them, this will cause them finally to fall into the sun.

If we, therefore, consider this revolving elementary matter of the world in that state into which it puts itself by attraction and by the mechanical consequence of the general laws of resistance, we see a region of space extending from the centre of the sun to unknown distances, contained between two planes not far distant from each other, in the middle of which the general plane of reference is situated. And this elementary matter is diffused in this space within which all the contained particles—each according to the proportion of its distance and of the attraction which prevails there—perform regulated circular movements in free revolutions. And hence, as in this arrangement they obstruct each other as little as possible, they would continue always in this relation, if the attraction of the elementary matters for each other did not then begin to produce its effect, and thereby give occasion to new formations which are the seed of the planets that are about to arise. For the elements which move round the sun in parallel circles and not at too great a difference of distance from the sun, are by the equality of their parallel motion almost at rest respectively towards each other; and thus the attraction of those elements there which are of higher specific attraction immediately produces an important effect, namely, the collecting of the nearest particles for the formation of a body which according to the proportion of the growth of its mass, extends its attraction farther and draws elements from a wide region to unite with it in its further formation.[1]

The view of the formation of the planets in this system has the advantage over every other possible theory in holding that the origin of the masses gives the origin of the movements, and the position of the orbits as arising at that same point of time; nay more, in showing that even the deviations from the greatest possible exactness in these determinations, as well as the accordances themselves, become clear at a glance.

[1] The beginning of the formation of the planets is not to be sought in the Newtonian Attraction alone. This force would in the case of a particle of such exceptional fineness, be far too slow and feeble. One would rather say that in this space the first formation takes place by the concourse of certain elements which are united by the usual laws of combination, till the mass which has arisen thereby has gradually grown so large that the Newtonian force of attraction in it has become powerful enough to increase it more and more by its action at a distance.

The planets are formed out of particles which at the distance at which they move, have exact movements in circular orbits ; *and therefore the masses composed out of them will continue the same movements at the same rate and in the same direction.* This suffices to show why the motion of the planets is almost circular, and why their orbits are in one plane. They would be exact circles[1] if the range out of which they collected the elements for their formation was very small, and then the difference of their movements would be very slight. But as a wide range of space is required in order that the dense mass of a planet may be formed out of the fine stuff which is so widely diffused in the celestial space, the difference of the distances which these elements have from the sun, and consequently also the difference of their velocities, is no longer insignificant. In consequence, it would be necessary, in order to maintain in the planet the equilibrium of the centripetal forces and the circular velocity with this difference of movements, that the particles which come together upon it from different distances with different movements should exactly compensate for the defects of each other. And although this really takes place with tolerable exactness,[2] nevertheless, as it falls some-

[1] This exact circular movement properly applies only to the planets near the sun ; for at the great distances where the most remote planets, or at least the comets, have been formed, it is easy to suppose that, as the falling movement of the elementary stuff was much feebler there, the extension of the space in which they were diffused was also greater, and that the elements there already diverge of themselves from the circular movement and must thereby be the cause of the bodies formed from them.

[2] For the particles in the region nearer the sun, which have a greater velocity of revolution than is required for the circular

what short of a perfect compensation, the result is divergence from the circular movement and eccentricity. It is as easily seen that, although the orbits of all the planets ought properly to be in one plane, yet even in this respect a small deviation is presented, because, as already mentioned, the elementary particles while situated as near as possible to the general plane of their movements, yet occupy some space on both sides of it. Now it would be a very happy chance if all the planets were to begin to form themselves exactly in the middle between these two sides in their relative plane, which already would bring about some inclination of their orbits to each other, although the tendency of the particles to limit this divergence on both sides, permits it only within very narrow limits. It is therefore not astonishing that the greatest exactness of determination is not to be found here any more than in any of the other products of nature, because the multiplicity of the circumstances which enter into every fact of nature does not admit of absolute regularity.

movement at the place where they collect upon the planet, compensate for what is lacking in the velocity of those particles which are more remote from the sun, and which become incorporated in the same body, in order that they may revolve in a circle at the distance of the planet.

SECOND CHAPTER.

OF THE DIFFERENT DENSITY OF THE PLANETS AND THE RELATION OF THEIR MASSES.

We have shown that the particles of the primitive elementary matter having been uniformly distributed by themselves in space would, by falling towards the sun, remain moving in the places where the velocity acquired by them in falling just attained equality with the attraction exerted upon them, and that their direction would be bent aside till it became perpendicular to the radius of their orbit, as ought to hold in circular movements.

But if we now consider particles of different specific density at the same distance from the sun, those of greater specific gravity press farther down through the resistance of the other particles towards the sun, and are not so soon bent aside from their paths as the lighter particles; and hence their movement becomes circular only when they approach nearer the sun. On the other hand, the elements of a lighter kind are sooner bent from the straight line of their fall, and turn into circular movements before they have penetrated so far towards the centre, and therefore will remain revolving at greater distances. They can neither penetrate so far through the space filled by the elements without their motion being weakened by the resistance of these elements, nor can they acquire the great degrees of velocity which are required for revolving nearer to the centre. Hence, after an equilibrium has been attained in their movements, the specifically lighter particles will revolve at further distances from the sun, while the heavier particles will be found at nearer distances; and those planets which are formed out of them, and which are nearer the sun, will therefore be denser than those which are formed further from it by the concurrence of these atoms.

It is therefore a sort of statical law that determines the distances of the matter in space according to the inverse ratio of its density. At the same time, it is just as easy to understand that each particular distance is not necessarily occupied only by particles of the same specific density. Of the particles of a certain specific kind some remain moving at greater distances from the sun, and those that have fallen from greater distances acquire at a greater distance the modification of their fall required for constant circular movement; and, on the other hand, those particles whose original position in the universal distribution of matter in its chaotic state was nearer the sun, notwithstanding their not being of greater density, will come nearer to it in their circle of revolution. And as the positions of the material elements, in respect to the centre of their attraction, are determined not only by their specific gravity but also by their original place in the first state of repose in nature, it is easy to understand that very different kinds of them will come together at every distance from the sun so as to remain suspended there. But it will be also understood that the denser materials will generally be found more abundantly at the centre than further from it; and therefore, notwithstanding that the planets will be mixtures of very diverse materials, yet generally their masses must be denser in the proportion in which they are nearer to the sun, and they must be of less density according as their distance from it is greater.

As regards this law ruling the density of the planets, our system shows a superiority over all other conceptions which have been formed, or can be formed, regarding its cause. Newton, who had determined the density of some of the planets by calculation, believed that the cause of its ratio being constituted according to their distance was to be found in the fitness of the Divine choice and in the motives of the Divine purpose. It was because the planets which are nearer the sun must endure more of its heat, while the more distant planets must do with less degrees of warmth; and this appears not to be possible unless the planets near the sun were composed of a denser matter, and the more distant ones of a lighter kind. But it does not require much reflection to perceive the inadequacy of such an explanation. A planet—for example, our earth—is composed of kinds of matter very different from each other. Of these it was necessary that the lighter particles, which are more permeated and moved by the same action of the sun, and whose composition has a ratio to the heat with which its rays operate, must be distributed on the surface. But it is not at all evident from this that the mixture of the other materials in the whole of the mass must have this relation; because the sun has no effect at all upon the interior of the planets. Newton was afraid that if the earth were plunged in the rays of the sun, as near it as Mercury, it would burn like a comet, and that its matter would not have sufficient fire-resisting power not to be dissipated by such heat. But how much more would not the proper matter of the sun itself, which is at least four times lighter than that of the earth, be destroyed by this glowing heat? And why is the moon twice denser than the earth, seeing that it revolves with it at the same distance from the sun? We cannot therefore attribute the proportioned densities of the planets to their relation to the heat of the sun without being involved in the greatest contradictions. We rather see that a cause which distributes the planets in their places according to the density of their mass, must have had a relation to their internal matter and not to their surface. It must, notwithstanding this result which it determined, still allow a diversity of material in the same heavenly body, and establish this relation of density only in the sum total of its composition. I leave it to the perspicuity of the reader to judge whether any other statical law than that which is presented in our theory, can satisfy all these conditions.

The relation between the densities of the planets involves another circumstance which, by its complete harmony with the explanation already indicated, corroborates the correctness of our theory. The heavenly body which stands in the centre of other orbs revolving round it, is usually lighter than the body which revolves nearest it. The earth compared with the moon, and the sun compared with the earth, show such a relation between their densities. According to the scheme which we have presented such a constitution is necessary. For as the inferior planets have been formed mainly from the outshot of the elementary matter which by the superiority of its density may have pressed so near to the centre with the requisite degree of velocity; on the other hand, the body in the centre itself has been heaped together without distinction of those materials of all existing kinds which have not attained to regular movements of their own. And as the lighter materials constitute the greatest portion of these various kinds of matter, it is easy to see that because the heavenly body, or any of the bodies revolving nearest the centre, contains as it were a selection of the denser kinds of matter, while the central body comprises in itself a mixture of them all without distinction, the substance of the former will be denser than that of the latter. And, in fact, the moon is twice denser than the earth, and the earth is four times denser than the sun, which according to all conjecture will be surpassed by still higher degrees of density by the nearer planets Venus and Mercury.

Our attention must now be directed to the relation which, according to our theory, the masses of the heavenly bodies ought to have in comparison with their distances, in order to test the result of our system by the infallible calculations of Newton. It does not need many words to make it intelligible that the central body must always be the chief member of its system, and consequently that the sun must be considerably greater in mass than the whole of the planets: a relation which will also hold good of Jupiter and Saturn when compared with their satellites. The central body is formed by the deposit of all the particles drawn from the whole range of its sphere of attraction which have not been able to obtain the precise determination of circular movement and the near relation to the common plane, and of which undoubtedly there must be an immensely greater multitude than of the latter. Now, let us apply this view in particular to the sun. If we would estimate the breadth of the space in which the revolving particles which have furnished their matter to the planets have diverged furthest from the common plane, it may be assumed to be somewhat greater than the extent of the greatest deviation of the planetary orbits from each other. But in their divergence from the common plane on both sides their greatest inclination to each other scarcely makes an angle of 7½ degrees. Thus all the matter out of which the planets have been formed may be represented as having been spread out in that space which was contained between two planes from the centre of the sun enclosing an angle of 7½ degrees. Now a zone of 7½ degrees in breadth going in a direction of the great circle of the sphere, is rather more than the seventeenth part of the surface of the sphere; and therefore the solid space between the two planes that bound the spherical space at the breadth of the angle mentioned is rather more than the seventeenth part of the volume of the whole sphere. Hence, according to this hypothesis, all the matter which has been employed for the formation of the planets constitutes about the seventeenth part of the matter which the sun has collected for its composition out of that range of space which extends to the furthest planet on both sides. But this central body has an excess of mass over the sum total of all the planets, such that it stands to the latter not as 17 : 2 but as 650 : 1, according to the calculation of Newton. And it is easy to see that in the regions of space beyond Saturn, where the planetary formations either cease or at least are rare, where only a few cometary bodies have been formed, and where the movements of the elementary matter has not been fitted to attain to regulated equilibrium with the central forces as in the region near the centre, but issue in an almost universal falling towards the centre and increase the sun with all the matter out of such widely extended ranges of space —it is evident, I say, that from these causes the bulk of the sun must attain to such a preponderating greatness of mass.

But in order to compare the planets with each other as regards their masses, we remark, first, that according to the mode of their formation as above indicated, the quantity of the matter which comes to compose a planet depends chiefly on its distance from the sun: (1) because the sun by its attraction limits the sphere of the attraction of a planet, but under similar circumstances it does not limit the more distant ones so strictly as those that are near; (2) because the circles out of which all the particles are derived to make up a planet, are described with a greater radius, and therefore contain more elementary matter within them, than the smaller circles; (3) because, for the reason now stated, the breadth between the two planes of greatest divergence in an angle of the same number of degrees is greater at great distances than at small. On the other hand, this advantage of the more distant planets over the inferior planets is limited by the fact that the particles nearer the sun will be of a denser kind and according to all appearance also be less scattered than those at a greater distance. But it may likewise be easily inferred that the former advantages do nevertheless far outstrip the latter limitations in being conducive to the formation of great masses, and generally the planets which are formed at a far distance from the sun must attain to greater masses than those that are near. This holds good, then, in so far as we imagine the formation of one planet only as going on in presence of the sun; but if we consider several planets as being formed at different distances, then the one will limit the range of the attraction of the other through its own sphere of attraction, and this brings about an exception to the former law. For that planet which is near another of preponderating mass will lose very much of the benefit of the sphere of its formation, and will thereby become much smaller than the proportion of its distance from the sun taken by itself alone would demand. Although, therefore, on the whole the planets have a greater mass according as they are further removed from the sun, and accordingly Saturn and Jupiter, the two chief members of our system, are the largest planets because they are furthest removed from the sun, yet there are found deviations from this analogy, in which however there is always conspicuously displayed the indication of the general mode of the formation of the heavenly bodies which we have asserted: namely, that a planet of exceptional largeness robs the nearest planets on both sides of the mass that properly belongs to them on account of their distance from the sun, by thus appropriating part of the materials which should go to their formation. In fact, Mars, which in virtue of its position ought to be larger than the earth, has been deprived of some of its mass by the attractive force of the enormous mass of Jupiter being near to it; and Saturn itself, although having an advantage over Mars by its distance, has not been completely freed from suffering a considerable loss through Jupiter's attraction. And it seems to me that Mercury owes the exceptional smallness of its mass not only to the attraction of the mighty sun being so near it, but also to the neighbourhood of Venus, which, if we compare its probable density with its magnitude, must be a planet of considerable mass.

Everything concurs as admirably as could be desired, in corroborating the sufficiency of a mechanical theory as an explanation of the origin of the construction of the world and of the heavenly bodies. Taking into account the space in which the constituent matter of the planets was scattered before their formation, we shall now proceed to consider what was the degree of tenuity of the matter which filled this intervening space, and with what sort of freedom and with how few obstructions the floating particles may have started on their regulated movements therein. If the space which held all the matter of the planets within it, was contained in that portion of the sphere of Saturn which is contained between two planes at an angle of between 2 degrees and 7 degrees and extending from the centre of the sun to all distances, and was therefore the seventeenth part of the whole sphere which can be described with the radius of the distance of Saturn; and if, in order to calculate the alteration of the primitive planetary matter when it filled this space, we take the distance of Saturn to be only 100,000 diameters of the earth: then the whole sphere of the orbit of Saturn would exceed in volume that of the earth 1000 bimillion times. And if instead of the seventeenth part we take only the twentieth of this sphere, the space in which the elementary matter was floating must still have exceeded the volume of the earth by 50 bimillion times. Now if we reckon the mass of all the planets with their satellites as, according to Newton, being $\frac{1}{650}$ of the sun, then the earth, which is only $\frac{1}{169282}$ of that mass, will be related to the whole mass of all the matter in the planets as 1 : 267½; and if all this matter were reduced to the same specific density as that of the earth, a body would arise out of it which would occupy 277½ times more space than the earth. Hence, if we assume the density of the earth in the whole of its mass to be not much greater than the density of the solid matter which is found under its outmost surface (as the properties of the figure of the earth just require this); and if we reckon this surface matter to be about four or five times denser than water, and water a thousand times heavier than air: then the matter of all the planets if they were expanded till they acquired the tenuity of the atmosphere, would occupy almost fourteen hundred thousand times greater space than does the present volume of the earth. This space when compared with the space in which, according to our supposition, all the matter of the planets was dispersed, is thirty million times less; and therefore the dispersion of the matter of the planets in this space would have a tenuity just as many times greater than that of the particles of our present atmosphere. In fact, this high degree of dispersion, however incredible it may appear, was nevertheless neither unnecessary nor unnatural. It was necessary that it should be as great as possible, in order to allow the floating particles all possible freedom of movement, almost as if they had been in a vacuum, and at the same time to diminish infinitely the resistance which they could make to each other. But these particles could of themselves assume such a state of attenuation, as cannot be doubted if we have any knowledge of the expansion which matter goes through when it is transformed into vapour, or—keeping to the heavens—when we consider the attenuation of matter in the tails of comets which, with such an enormous thickness across as exceeds the diameter of the earth by at least a hundred times, are yet so transparent that the small stars may be seen through them, whereas our atmosphere when it is illuminated by the sun does not allow this at a height which is many thousand times less.

I conclude this chapter by adding an analogy which by itself alone can raise the present theory of the mechanical formation of the heavenly bodies above the probability of an hypothesis, and carry it up to a formal certainty. If the sun is composed of particles of the same primary matter out of which the planets have been formed, and if the only difference between them consists in this, that in the sun matter of all kinds is accumulated without distinction, whereas in the planets it has been distributed at different distances according to the condition of the density of its kinds: then, if we consider the matter of all the planets as combined together, from their total mixture there would result a density almost equal to the density of the body of the sun. Now this necessary consequence of our system finds a happy confirmation which M. de Buffon, that deservedly celebrated philosopher, has instituted between the densities of the whole matter in the planets and the sun. He found a proportion between them as close as that between 640 and 650. If the natural and necessary consequences of a theory find such happy confirmation in the actual relations of nature, is it possible to believe that mere chance causes this agreement between the theory and the observation?

THIRD CHAPTER.

OF THE ECCENTRICITY OF THE ORBITS OF THE PLANETS AND THE ORIGIN OF THE COMETS.

It is not possible to regard the comets as a peculiar species of heavenly bodies entirely distinct from the race of planets. Nature works here as elsewhere by insensible gradations; and in passing through all stages of change it connects remote qualities with those that are near, by means of a chain of intervening members. In the case of the planets, their eccentricity is a consequence of a deficiency in that effort by which nature strives to make the planetary movements exactly circular, but which it can never completely attain on account of the intervention of diverse circumstances; and the conditions are such that the deviation is greater at greater distances than at near.

This modification passes through a constant gradation, by all possible degrees of eccentricity, from the planets at last to the comets. And although this connection seems to be interrupted at Saturn by a great gulf which completely separates the race of comets from the planets, yet, as we have remarked in the first part of this essay, it is probable that there may be other planets beyond

Saturn which, by their greater deviation from the path of circular orbits, approach nearer that of comets, and that it is only owing to the want of observation, or even to the difficulty of it, that this affinity has not been long since presented as visibly to the eye as it appears to the understanding. In the first chapter of this Second Part of our Essay, we have already indicated a cause which can make eccentric the orbit of a heavenly body that is forming itself out of the matter floating around it, although it is held that this matter in all its positions possesses forces exactly determined for circular motion. For as the planet gathers them from distances far apart from each other and where the velocities of the circular paths are different, these forces come together in it with various degrees of revolving motion inherent in them which deviate from the ratio of the velocity that corresponds to the distance of the planet, and thereby cause an eccentricity in its orbit, in so far as their different impacts want the particles required to compensate completely for their deviation from each other.

If the eccentricity of the heavenly bodies had no other cause than this, it would be everywhere kept within moderate bounds. It would also be less in the small planets and those that are far removed from the sun than in those that are near and large, on the supposition that the particles of the primitive matter actually had previously exact circular movements. But these determinations do not agree with observation; because, as already remarked, the eccentricity increases with the distance from the sun and the smallness of the masses appears rather to make an exception to the increase of the eccentricity as seen in Mars. Hence, we are compelled to limit the hypothesis of the exact circular movement of the particles of the primitive matter to this extent that, as they come very close to this exact determination in the regions near the sun, yet they allow a wider divergence from it the more distantly these elementary particles have floated away from the sun. Such a modification of the principle of the free circular movement of the primitive matter is more conformable to nature. For notwithstanding the rarity of space which seems to leave them freedom to limit each other at the point of the complete equilibrium of the central forces, yet the causes are not less important which hinder the full realization of this purpose of nature. The further the scattered portions of the primitive matter are removed from the sun, so much the weaker is the force which draws them towards it; and the resistance of the nearer portions of this primitive matter, which has to bend its falling motions sideways and compel it to assume a direction perpendicular to the radius, diminishes in the proportion in which these nearer particles move away under it either to be incorporated in the sun or to enter upon revolutions of their own in nearer regions. The specifically preponderating lightness of this more distant matter does not allow it to assume the falling movement towards the sun, which is the foundation of the whole system, with the energy that is required to make the resisting particles give way; and perhaps these distant particles still limit each other so as, after a long period, finally to overcome this uniformity. And thus small masses have already been formed among them as the beginnings of so many heavenly bodies which, as they are collected out of feebly moved matter, just acquire an eccentric movement with which they fall to the sun, and on their way they become bent more and more from the perpendicular line of falling by the incorporation of other rapidly moving portions of matter; yet at the end they remain comets if those regions of space in which they have formed themselves, have become cleared and empty, by the matter it contained falling into the sun or being collected into separate masses. This is the cause of the eccentricities of the planets increasing with their distances from the sun, which also holds good of those heavenly bodies that are called 'comets,' because they exceed the planets in this respect. There are indeed two exceptions which interrupt the law of the eccentricity increasing with the distance from the sun, and these are found in the two smallest planets of our system—Mars and Mercury. But with regard to the former, it is probably the neighbourhood of the very large planet Jupiter which, by attraction on its side, has robbed Mars of the particles needed for its formation, and has left it only space to increase in towards the sun, thereby causing an excess of the central force and eccentricity. And as regards Mercury, the nearest but also the most eccentric among the planets, it is easy to perceive that because the sun in its rotation comes far short of the velocity of Mercury, the resistance which it offers to the matter in the space surrounding it will not only deprive the nearest particles of their central movement, but that this resistance may easily extend to Mercury and will have thereby considerably diminished the velocity of its revolution.

The most distinctive mark of the comets is their eccentricity. Their atmospheres and tails, which on their great approach to the sun are spread out by its heat, are only consequences of it, although in ages of ignorance, as unusual objects of terror, they have been regarded by the common people as foretelling imaginary fates. The astronomers, who give more attention to the laws of their movements than to the strangeness of their form, observe a second characteristic which distinguishes the comets from the planets, namely, that they are not confined like the latter to the zone of the zodiac, but revolve freely in all quarters of the heavens. This peculiarity has the same cause as their eccentricity. If the planets have their orbits included within the narrow region of the zodiac, it is because the elementary matter near about the sun obtains circular movements which at every revolution have tended to intersect the plane of relation, and do not allow the body once formed to deviate from this plane to which all the matter presses from both sides. Hence the primitive matter in the regions of space far away from the centre and which is feebly moved by attraction, cannot attain to free circular revolution; and from this very cause, which produces the eccentricity, it is not able to accumulate at that distance at the plane of the relation of all the planetary movements, or so as to maintain the bodies formed there specially in this track. Rather will the scattered primitive matter, since it is not limited to a particular region as is the case with the inferior planets, form itself into heavenly bodies as easily on one side as on the other, and just as frequently far from the common plane of relation as near to it. Hence the comets will come to us without restriction from all quarters; yet those whose first place of formation was not removed far beyond the orbits of the planets will show less deviation from the limit of their paths, as well as less eccentricity. This lawless freedom of the comets in regard to their deviations, increases with their distances from the centre of the system. And in the depths of the heavens it is lost in a complete absence of revolution, which leaves the extreme bodies that are being formed to fall freely to the sun, and thus puts the farthest limits to the constitution of the system.

In this sketch of the movements of the comets, I assume that as regards their direction they will have it mostly in common with the planets. This appears to me to be indubitable in the case of the near comets; and this uniformity cannot be lost in the depths of the heavens nearer than where the elementary primitive matter in the utmost faintness of motion sets up the rotation which arises so far in all directions by its fall. And this is so, because the time which is required by the combination of the lower movements to make them accordant in their direction, is, on account of the intervening distance (notwithstanding that the formation of nature is accomplished in the nearer region), too long for them to extend to it. There may thus perhaps be comets which perform their revolution towards the opposite side, namely, from east to west; although, from reasons which I shrink from assigning here, I would almost like to persuade myself that of nineteen comets in which this peculiarity has been observed, in some cases an optical illusion may have given occasion to it.

I must still make some further remarks concerning the masses of the comets and the density of their matter. For the reasons advanced in the last chapter, in the more remote regions where these heavenly bodies are formed, there should rightly be formed masses greater and greater according to the ratio in which their distance increases.

It is also credible that some comets are larger than Saturn and Jupiter; although it cannot be believed that the magnitude of their masses always goes on thus increasing. The dispersion of the primitive matter and the specific lightness of its particles will make the formation of bodies slow in the most remote regions of space; and the indefinite diffusion of it in the immeasurable range of this distance, without any determination to accumulate towards a certain plane, allows the formation of many smaller masses instead of one single huge formation, while the weakness of the central force will let the greatest portion of the particles be drawn to the sun before they have collected into masses.

The specific density of the matter out of which the comets arise is more remarkable than the magnitude of their masses. As they are formed in the furthest region of the universe, it is probable that the particles of which they are composed are of the lightest kind; and it cannot be doubted that this is the chief cause of the vapour heads and tails by which they are distinguished from other heavenly bodies. This dispersion of the matter of the comets into vapour cannot be attributed mainly to the action of the heat of the sun; for some comets scarcely reach as near the sun as the distance of the earth's orbit; and many stop between the orbits of the earth and Venus, and then turn back. If such a moderate degree of heat resolves and attenuates the matter on the surface of these bodies to this degree, must they not consist of the very lightest stuff which can suffer more attenuation by heat than any other matter in the whole of nature?

Nor can these vapours so frequently rising from comets be attributed to the heat which the body of the comet has preserved from its previous proximity to the sun. For it may be conjectured that a comet at the time of its formation has passed through several revolutions with greater eccentricity, and that these have been only gradually diminished; but the other planets of which the same may be supposed, do not show this phenomenon. Nevertheless, they would show it in themselves if the kinds of lightest matter, which are included in the composition of the planet, were present in it as abundantly as in the comets.

The earth has in it something which may be compared with the expansion of the vapours of comets and their tails, namely, the Northern Lights, or Aurora Borealis. The finest particles which the action of the sun draws from its surface, accumulate around one of the poles when the sun is going through the half of its course in the opposite hemisphere. The finest and most active particles which ascend in the Torrid Zone, when they have attained a certain height in the atmosphere, are forced by the action of the rays of the sun to retreat and to accumulate in those regions which are then turned away from the sun and buried in a long night; and they make up to the inhabitants of the Arctic Zone for the absence of the great light which sends to them even at that distance the effects of its warmth. The same force of the rays of the sun, which makes the Aurora Borealis, would produce a vapour head with a tail, if the finest and most volatile particles were to be found as abundantly on the earth as on the comets.

FOURTH CHAPTER.

OF THE ORIGIN OF THE MOONS AND THE MOVEMENTS OF PLANETS ROUND THEIR AXES.

THE striving of a planet to form itself out of the contents of the elementary matter, is at the same time the cause of its axial rotation, and it also produces the moons that are to revolve around it. What the sun with its planets is on the great scale, is represented on a smaller scale by a planet which has a widely extended sphere of attraction; that is to say, it is the head of a system whose members have been put into motion by the attraction of the central body. The planet while forming itself, in setting the particles of the primitive matter into motion for its formation through the whole range of its attraction, will out of all these falling movements by means of their reciprocal action produce circular movements, and at last such movements as result in a common direction; and part of these movements will obtain the proper modification into a free circular path, and by this restriction they will be found near a common plane. In this space, just as the sun forms the planets so do the planets form the moons, when the distance of the attraction of these heavenly bodies presents favourable conditions for their production. Moreover, what has been said regarding the origin of the Solar System may be applied equally well to the System of Jupiter. The moons will all have the orbits of their revolution directed to one side, and almost in one plane; and this from the same causes that determine the analogy in the great system. But why do these satellites move in their common direction towards the side on which the planets revolve rather than to any other side? Their revolutions are not produced at all by the orbital movements of the planets. They merely recognize the attraction of the planet as a cause of their movement, and as regards this attraction all directions are indifferent; a mere chance will decide for one out of all possible directions in accordance with which the falling movement of the matter turns into orbits. In fact, the circular course of the planet does nothing to impress on the matter out of which the moons are to be formed, revolutions round it; all the particles around the planet move in the same motion with it round the sun, and are therefore in relative rest towards it. The attraction of the planet alone does everything. But the orbital movement which has to arise from that attraction, seeing that it is absolutely indifferent as regards all the directions, needs only a small external determination to be turned to the one side rather than the other; and this small degree of divergence it obtains from the advancing of the elementary particles which revolve at the same time around the sun with it but with more velocity, and which come into the sphere of the attraction of the planet. For this compels the particles nearer the sun, which are revolving with more rapid motion, to leave the direction of their track when still far off and to rise over the planet in an elongated sweep. And because these particles have a greater degree of velocity than the planet itself when they are made to fall by its attraction, they give to their rectilinear fall, and also to the fall of the other particles, an inclination from west to east; and this slight deviation is all that is needed to cause the circular motion into which the falling movement started by the attraction passes, to take this direction rather than any other. For this reason all the moons will agree in their direction with the direction of their revolution. But neither can the plane of their path deviate far from the plane of the orbits of the planets, because the matter out of which they are formed—from the same reason that we have adduced for their direction—is likewise inclined to this precise determination of these orbits, namely, to coincidence with the plane of the principal orbits.

From all this we see clearly what are the circumstances and conditions under which a planet can obtain satellites. The force of its attraction must be great, and consequently the range of its sphere of attraction must be widely extended, in order that the particles moving through a long fall towards the planet may, notwithstanding what is destroyed by resistance, yet acquire sufficient velocity for them to revolve freely, and also in order that sufficient matter may be present in this region for the formation of moons; and this cannot be realized with a feeble attraction. Hence only those planets which are of great mass, and at a far distance, are provided with satellites. Jupiter and Saturn, the two greatest, and also the most distant among the planets, have most moons. The earth, which is much smaller than they are, has only acquired one; and Mars, which on account of its distance might have shared in this advantage, goes empty away because its mass is so small.[1]

It is a pleasure to see how this same attraction of the planet, which procured the matter for the formation of the moons and at the same time determined their movement, extends to its own body and communicates to it, by the same action through which it is formed, a rotation around its axis in the general direction from west to east. The particles of the primitive falling matter which, as has been said, obtain a universal rotating movement from west to east, mostly fall on the surface of the planet and become mixed up with its mass, because they have not the requisite degrees of velocity to maintain themselves suspended freely in circular movements. Entering now into the composition of the planet they must, as parts of it, continue the same revolution in the same direction which they had before they were united with it. And it can be seen generally from what precedes, that the multitude of the particles which the want of the required motion precipitates on the central body, must very far exceed the number of the other particles which may have acquired the requisite degrees of velocity. And hence it is easy to understand why this central body in its axial rotation will come far short of having the velocity required to produce an equilibrium between the gravitation on its surface and the centripetal force; and yet in planets of great mass and at a remote distance, it will be more rapid than in near and small planets. In fact Jupiter has the rapidest axial rotation

[1] But see note on p. 47.—Tr.

that we know; and I do not understand by what system this could be harmonized with a body whose mass exceeds all the rest, unless this motion itself is to be regarded as the effect of that attraction which this heavenly body exercises according to the ratio of that same mass. If the axial rotation were the effect of an external cause, then Mars ought to have a more rapid rotation than Jupiter; for the same moving force moves a smaller body more than a larger one. And it would justly astonish us, seeing that all movements decrease as they are further from the centre, that the velocities of the rotations should increase with the same distances, and in the case of Jupiter could be even two and a half times quicker than that of its annual movement.

As we are therefore forced to recognize in the daily rotations of the planets the very same cause which is the universal source of motion in nature—namely, Attraction—this mode of explanation will authenticate its correctness by the natural claim of its fundamental conception, and by such unforced inferences from it.

But if the formation of a body does itself produce the rotation round its axis, then all the orbs of the universe must have this rotation. Why, then, has the moon not got it; for the moon, according to some (although erroneously) seems to derive that sort of rotation by which it always turns the same side to the earth rather from a preponderance of one hemisphere than from an actual motion of revolution? May it not, in fact, have formerly turned more rapidly round its axis, and by some unassigned causes which gradually diminished it this motion has been brought to this small and proportioned remainder? We have only to solve this question in regard to one of the planets and the solution will then be immediately applicable to them all. I reserve this solution for another occasion, because it is necessarily connected with the problem which the Royal Academy of Sciences at Berlin have proposed as the subject of their prize for the year 1754.[1]

The theory which goes to explain the origin of the axial rotations, must also be able to derive the position of their axes towards the plane of their orbits from the same causes. We have reason to wonder why the equator of the diurnal rotation is not in the same plane with that of the orbits of the satellites which revolve around the same planet; for the same movement which has directed the revolution of a satellite, from its extending to the body of the planet, ought to have produced its rotation around its axis, and communicated to it the same determinate direction and position. Heavenly bodies which have no satellites revolving round them do, nevertheless, put themselves into axial rotation by this same movement of the particles which made up their matter, and by the same law which restricted them to the plane of their periodic path of revolution, which, for the same reasons, must coincide in direction with the plane of their orbit. In consequence of the action of these causes the axes of all the heavenly bodies ought properly to be perpendicular to the universal relative plane of the planetary system, which does not deviate far from the ecliptic. But the axes are only perpendicular in the two most important members of this system, Jupiter[2] and the Sun.

[1] Kant discusses and solves this question in his remarkable tractate (translated above) entitled: *Examination of the Question whether the Earth has undergone an alteration of its Axial Rotation.* 1754.—Tr.

[2] Jupiter has a small inclination of somewhat over 4 degrees.

All the other members whose rotation is known incline their axes to the plane of their orbits; Saturn more than the others, but the Earth more than Mars, whose axis is also directed almost perpendicular to the ecliptic.[1] The equator of Saturn (in so far as we may regard it as indicated by the direction of its ring) is inclined to the plane of its path at an angle of 31 degrees, while the Earth has an inclination to its path of 22½ degrees.[2] The cause of these deviations may perhaps be referred to inequality in the movements of the matter which has been conjoined to form the planet. The principal movement of the particles in the direction of the plane of its orbit, was around the centre of the planet; and the common plane lay there around which the elementary particles accumulated to make the movement circular there if possible, and to accumulate matter for the formation of the satellites, which, on that account, never deviate far from the plane of the orbit. If the planet formed itself for the most part only out of these particles, its axial rotation at its first formation would have diverged as little from it as the satellites do; but it formed itself, as the theory has shown, more out of the particles which sank to it from both sides, and the quantity or velocity of which seems not to be so completely balanced as that the one hemisphere should not have been able to get a slight excess of movement over the other, and therefore acquire a certain deviation of the axis.

Notwithstanding these reasons, I present this explanation only as a conjecture, which I do not pretend to have established. My real opinion amounts to this: that the

[1] Mars has an inclination of about 29 degrees.—Tr.

[2] Saturn's inclination is 26° 49′; that of the Earth 23° 27′.—Tr.

rotation of the planets round their axes, in the original state of their first formation, coincided pretty exactly with the plane of their annual path, and that there have been causes at work which have pushed this axis out of its first position. A heavenly body which passes out of its first fluid condition into the solid state, when it develops itself completely in this way, undergoes a great alteration in the regularity of its surface. This becomes fixed and hardened, whereas the deeper materials have not yet sunk sufficiently in accordance with the ratio of their specific gravity. The lighter kinds of matter, which were intermingled in the common mass, ultimately find their place after they have separated from the others beneath the outermost part, the now fixed crust, and produce the great cavities which—from causes which it would take too long to state here—are found to be largest and broadest under or near the equator; and into these the said crust ultimately sinks, and produces thereby manifold inequalities in mountains and valleys. Now, if the surface became uneven in this way, as must manifestly have been the case with the Earth, the Moon, and Venus, it cannot have been able any longer to maintain on all sides the equilibrium of the revolution in its axial rotation. Certain protuberant parts of considerable mass, which found no others on the opposite side that could furnish a counteraction to their strain, must then displace the axis of rotation and tend to put it into a new position, around which the matter of the rotating body would be kept in equilibrium. The same cause, then, which in the completion of the formation of a heavenly body has changed its surface from a level state into broken inequalities—that general cause which is discerned in all the heavenly bodies which can be distinctly enough perceived by the telescope—has subjected them to the necessity of somewhat altering the original position of their axes. But this alteration has its limits so that it may not diverge too far. As already mentioned, the inequalities of the surface are produced more in the neighbourhood of the equator of rotating globes than at a distance from it; at the poles they almost entirely disappear, the causes of which are reserved for discussion in another connection. Hence the masses which tower highest above the common plane will be met with near to the equinoctial circle; and as these masses tend to approach that circle from the excess of their impulsion or swing, they will be able to raise the axis of the heavenly body out of the position perpendicular to the plane of its path at most only by a few degrees. In consequence of this, a heavenly body which has not yet completed its formation will still have this perpendicular relation of the axis to its orbit, which it will perhaps alter only after long centuries. Jupiter seems still to be in this state. The preponderance of its mass and magnitude, and the lightness of its matter, have forced it to overcome the fixed repose of its constituent matter some centuries later than other heavenly bodies. Perhaps the interior of its mass is still in motion carrying down the parts of its composition to the centre according to the state of their gravity, and, by separation of the thinner kinds from the heavier, bringing about the state of solidity. Under such conditions things cannot yet appear at rest upon its surface. Upheavals and wreckage prevail upon it. The telescope itself has assured us of this. The form of this planet is constantly altering, whereas the Moon, Venus, and the Earth maintain the same shape unchanged. We may also reasonably enough imagine as coming some centuries later the completion of the period of formation of a heavenly body which exceeds the magnitude of our earth more than twenty thousand times, while its density is four times less than that of the earth. If its surface has reached a state of rest, undoubtedly far greater inequalities than those which cover the surface of the earth, combined with the rapidity of its swing, will communicate to its rotation in a not very long period that constant position which the equilibrium of the forces upon it will demand.

Saturn, which is three times smaller than Jupiter, may perhaps, from its greater distance, have received the advantage of a more rapid completion of its formation. At least its much more rapid rotation and the great proportion of its centrifugal force to the gravity on its surface (which will be shown in the following chapter) brings it about that the inequalities supposed thereby to be produced upon it, have very soon counterbalanced that preponderance by a displacement of the axis. I freely confess that this part of my system regarding the position of the axes of the planets is still incomplete, and pretty far from having reached the point at which it could be made the subject of mathematical calculation. I have preferred honestly to avow this rather than to endanger the substantiality of the rest of my theory by supporting it by all sorts of specious reasons, and thus giving it a weak side. The following chapter may furnish confirmation of the credibility of the whole hypothesis by which I have attempted to explain the movements of the universe.

FIFTH CHAPTER.

OF THE ORIGIN OF SATURN'S RING AND CALCULATION OF THE DIURNAL ROTATION OF THIS PLANET FROM ITS RELATIONS.

In virtue of the Systematic Constitution in the Universe, its parts are connected by a gradual modification of their special characteristics; and it may be conjectured that a planet situated in the remotest region of the world, will have almost the same characteristics as the nearest comet would assume if it were raised by the diminution of its eccentricity into the order of planets. We shall accordingly consider Saturn as if it had passed through several revolutions with greater eccentricity in a manner similar to the movement of comets, and that it had gradually been brought into a path more resembling a circle.[1] The heat which was incorporated in it at its perihelion raised the light matter from its surface; which matter, as we know from the former chapters, is of extreme tenuity in the farthest planets, and in this state it is readily expanded by small degrees of heat. Nevertheless, after the planet had been brought during a certain

[1] Or, it is more probable, that in its comet-like state—which it still exhibits in virtue of its eccentricity—before the lightest matter of its surface was completely dispersed, it had diffused a cometic atmosphere.

number of revolutions to the distance at which it now revolves, in such a tempered climate it gradually lost the heat it had received; and the vapours which, rising from its surface, were diffused more and more around it, gradually ceased to spread out into tails. Nor did new vapours ascend any longer in such abundance as to increase those already given off; in short, the vapours already surrounding it continued—by causes which we will immediately mention—to float round it and preserved to it the mark of its former comet-like nature in a constant Ring, notwithstanding that its body exhaled the heat in it, and at last became a settled and purified planet. We shall now indicate the secret of the process that enabled the planet to preserve its ascending vapours in a freely floating state; nay, that has changed them from an atmosphere diffused around it into the form of a ring entirely separated from it. I assume that Saturn had a rotation round its axis; and nothing more than this is necessary to unveil the whole mystery. No other mechanism than this alone has brought about the said phenomenon on the planet by an immediate mechanical result; and I make bold to affirm that in the whole of nature there are but few things that can be referred to so intelligible an origin as this peculiarity of the heavens, which may be shown to have evolved itself out of the rude state of its first formation.

The vapours that ascended from Saturn had that movement in themselves which they had had as parts of its surface in its rotation round its axis, and continued freely so to move at the height to which they had ascended. The particles which ascended near the equator of the planet must have had the most rapid movement; and from the equator to the poles their motion must have been the slower according as the latitude of the place from which they ascended was higher. The ratio of their specific gravity regulated the different heights to which the particles ascended. But only those particles could maintain the place of their distance in a constantly free revolution, in whose case the distances to which they were transported demanded such a central force as they could sustain by the velocity which they possessed from the axial rotation. The remaining particles, in so far as they could not be brought to this exact relation by the reciprocal action of the rest, must either be removed by the excess of their motion out of the sphere of the planet, or, from deficiency of it, must have been compelled to fall again upon it. The particles scattered through the whole extent of the sphere of the vapour, in virtue of the same central laws, tended in the movement of their revolution to cut through the prolonged plane of the equator of the planet on both sides; and as they would arrest each other in this plane from both hemispheres, they would accumulate there. And as I assume that the said vapours are those which the planet sent up last as it cooled, all the dispersed vaporous matter would be collected near this plane in a not very broad space, and the spaces on either side would be left empty. In this new and altered direction, however, they would still continue the same movement which kept them floating in free concentric circular orbits. In this manner, then, the circle of vapour altered its shape, which was that of a full sphere, into the form of an out-spread disc which coincided exactly with the equator of Saturn. But, owing to the same mechanical causes, this expanse could not but at last assume the form of a Ring whose outer border was determined by the action of the rays of the sun, which by its force scattered and removed those particles which had become removed to a certain distance from the centre of the planet, just as it does in its action on comets, and thereby marks off the outer limit of their atmospheres. The inner border of this Ring thus coming into existence, was determined by the ratio of the velocity of the planet at its equator. For at that distance from its centre where this velocity produces equilibrium with the attraction of the place, is the nearest point at which the particles ascending from its body can describe circular orbits through the motion proper to the axial rotation. The nearer particles—seeing that they required a greater velocity for such a revolution, which they nevertheless could not possess, because even at the equator of the planet the movement is not more rapid—would thereby obtain more eccentric paths which would cross each other, would weaken each other's motion, and finally would be all precipitated upon the planet from which they had risen.

This strange and rare phenomenon presents a spectacle which has always astonished the astronomers since its discovery, and the cause of which no one has ever been able to entertain a probable hope of discovering. But we now see how it has arisen in an easy mechanical way that is explicable without any new hypothesis. What has happened in the case of Saturn—as may easily be perceived—would occur just as regularly in the case of every comet which had sufficient axial rotation, if it were transported to a constant distance at which its body could be gradually cooled. Nature is fruitful even amid chaos, of admirable developments in the exercise of the forces entrusted to her; and the product formed by them brings with it such magnificent relations and harmonies for promoting the common good of the creature that, even in the eternal and immutable laws of their essential properties, they enable us with unequivocal certainty to recognize that Great Being in whom they are all combined, in virtue of their common dependence, into a universal harmony.

Saturn derives great benefit from its ring. It prolongs its day, and along with so many moons it illuminates its night to such a degree that one might easily there forget the absence of the sun. But must we therefore deny that the universal evolution of matter through mechanical laws, without the need of any other than their universal determinations, has been able to produce relations which create such advantages for the rational creature? All existing beings depend on One Cause, which is the intelligence of God; they can therefore bring no other consequences with them than such as carry with them a representation of the perfection which is included in the Divine idea.

We shall now calculate the period of the rotation of this planet from the relations of its ring, according to the hypothesis now advanced as to its production. Since the whole movement of the particles of the ring is an incorporated motion derived from the axial rotation of Saturn on whose surface they were once found, the most rapid motion among the motions of these particles will coincide with the most rapid rotation that is found on the surface of Saturn; that is to say, the velocity with which the particles of the ring revolve at its inner border is equal to the velocity which the planet has at its equator. But the value of the former can be easily found by deducing it from the velocity of one of the satellites of Saturn, by taking the same as standing in the ratio of the square root of the distances from the centre of the planet. The velocity thus found immediately gives the time for the rotation of Saturn round its axis: *it is six hours, twenty-three minutes, and fifty-three seconds.* This mathematical calculation of the unknown movement of a heavenly body, which is perhaps the only prediction of its kind in natural science proper, awaits verification by the observations of future times. The telescopes yet known in our time do not magnify Saturn so much that the spots which may be supposed to exist on its surface, could be discovered by them so as to make out by their displacement its rotation around its axis. But telescopes have perhaps not yet attained all that perfection which may be hoped for, and which the industry and dexterity of the mechanicians appear to promise. If the day should ever come when our conjectures would be verified by actual inspection, what certainty would not our theory of Saturn thereby acquire and what pre-eminent credibility would not be gained for the whole of our system which is founded upon the same principles?[1] The period of the diurnal rotation of Saturn also yields the ratio of the centrifugal force of its equator to the gravitation upon its surface; the former is to the latter as 20 : 32. The gravitation is therefore only about $\frac{3}{5}$ths greater than the centrifugal force. This comparatively large ratio necessarily causes a very considerable difference between the diameters of this planet; and one might suspect that it must turn out so great that observation of this planet, although but little

[1] From telescopic observation the time of rotation is now given as about 10 hours, 14 minutes, 24 seconds.—Tr.

magnified by the telescope, must yet find it very distinctly perceivable by the eye. But this is not actually the case, and the theory might seem to be prejudicially affected thereby. A thorough examination wholly removes this difficulty. According to the hypothesis of Huygens, which assumes that gravitation is everywhere the same in the interior of a planet, the difference of the diameters is in a twice smaller ratio to the diameter of the equator than what the centrifugal force has to gravitation at the poles. For example, in the case of the earth the centrifugal force of the equator is $\frac{1}{289}$th of gravitation at the poles; and hence according to Huygens' hypothesis the equatorial diameter is $\frac{1}{578}$th greater than the axis of the earth. The cause is this: since, according to the hypothesis, gravitation in the interior of the globe is as great at all the points near the centre as on the surface, but at the same time the centrifugal force diminishes with the approach to the centre, the centrifugal force is not everywhere $\frac{1}{289}$th of the gravitation; and the whole diminution of the weight of a liquid column in the plane of the equator, for this reason, amounts not to $\frac{1}{289}$th but rather to the half of it, *i.e.* $\frac{1}{578}$th. On the other hand, in Newton's hypothesis the centrifugal force, which causes the axial rotation, has, in the whole plane of the equator down to the centre, an equal proportion to the gravitation of the place; because in the interior of the planet (if it is assumed to be of uniform density through and through) this force diminishes with the distance from the centre in the same proportion as the centrifugal force, and consequently the latter is always $\frac{1}{289}$th of the former. This causes a lightening of liquid columns in the plane of the equator, as also the rise of them by $\frac{1}{289}$th. And this difference of the diameters in this theory is further increased by the fact that the shortening of the axis, or polar diameter, brings with it an approach of the parts to the centre, and consequently an increase of the gravitation, while the prolongation of the equatorial diameter brings with it an increase of the distance of the parts from the same centre, and therefore a diminution of their gravity; and for this reason the flattening of Newton's spheroid is so increased that the difference of the diameters is raised from $\frac{1}{289}$th to $\frac{1}{230}$th.

For these reasons the diameters of Saturn must stand to each other in a still greater ratio than that of 20 : 32; they must almost attain to the proportion of 1 : 2. This is a difference which is so great that the least attention would not fail to observe it, however small Saturn may appear through the telescope. But from this it is only to be inferred that the hypothesis of uniform density, which appears to be applicable with tolerable correctness to the earth, deviates very far indeed from the truth in the case of Saturn. And this is already probable of itself in a planet whose mass consists in the greatest part of its contents of the lightest materials, and which allows the elements of a heavier kind in its composition to sink far more freely to the centre in accordance with the nature of their gravity before it obtains the solid state, than in the case of those planets whose much denser matter retards the settling down of their materials and so lets them become solid before this precipitation can take place. If we therefore suppose in the case of Saturn that the density of the matter in its interior increases with the approach to its centre, then gravity no longer diminishes in that ratio, but the growing density compensates for the deficiency of the parts which are placed beyond the distance of any point situated in the planet and which contribute nothing by their attraction to its gravity.[1] When this superior density of the deepest matter is very great, in virtue of the laws of attraction it transforms the gravity that diminishes in the interior towards the centre into an almost uniform force and brings the ratio of the diameters nearer to that given by Huygens, which is always the half of the ratio of the centrifugal force to the gravity. Consequently, as these were to each other as 2 : 3, the difference of the diameters of this planet will not be $\frac{1}{3}$ but $\frac{1}{6}$ of the equatorial diameter. And, finally, this difference is further concealed by the fact that Saturn, whose axis is always at an angle of 31 degrees to the plane of its path, never presents its position exactly in the direction of its equator as Jupiter does; and this diminishes the difference in its appearance almost by $\frac{1}{3}$. In these circumstances, and especially at the great distance of this planet, it is easy to see that the flattened form of its body will not be so easily discernible by the eye as might be thought. Nevertheless astronomy, whose progress mainly depends upon the perfection of its instruments, will yet perhaps, if I do not flatter myself too much, be put by their aid into a position of reaching the observation of such a remarkable property.

What I have been saying about the figure of Saturn may

[1] For, according to Newton's Laws of Attraction, a body which is situated in the interior of a ball is attracted only by that part of it which is comprised in a sphere described round it at its distance from the centre. The concentric part situated beyond that distance, on account of the equilibrium of its attractions which annul each other, does nothing to move the body either to the centre or away from it.

serve in some measure to establish a general remark concerning the Theory of the Heavens. Jupiter by exact calculation has at its equator a ratio of the gravity to the centrifugal force of at least $9\frac{1}{4}:1$; and, if its mass were of uniform density throughout, it ought, according to the principles of Newton, to show a still greater difference than $\frac{1}{9}$th between its axis and its equatorial diameter. But Cassini has found it to be only $\frac{1}{16}$ and Pound $\frac{1}{12}$, sometimes $\frac{1}{14}$; and at least all their different observations—which by their difference establish the difficulty of this calculation—agree in making it much less than it should be according to Newton's system, or rather according to his hypothesis of uniform density. And hence, if the hypothesis of uniform density which occasions such a great deviation of the theory from observation is changed into the much more probable view, in which the density of the mass of a planet is represented as increasing towards its centre, then we shall not only justify the observations on Jupiter, but even in the case of Saturn, a planet much more difficult to gauge, we shall be able distinctly to understand the cause of a less flattening of its spheroidal body.

From the mode of the formation of Saturn's ring we have found occasion to hazard the bold step of determining by calculation the time of its axial rotation, which the telescopes are not able to discover. Let us increase the example given of a physical prediction by the addition of another in reference to the same planet, which also will have to wait for the evidence of its correctness from the more perfect instruments of future times.

According to the supposition that Saturn's ring is an accumulation of the particles which, after they had ascended from the surface of that planet as vapours, have kept revolving freely in circles at the height of their distance in virtue of the momentum which they derived from its axial rotation and still carry on, the particles have not equal periodic revolutions at all their distances from the centre. On the contrary, they are related to each other as the square roots of the cubes of their distances, if they continue revolving according to the laws of the central forces. Now, according to this hypothesis the time in which the particles of the inner rim perform their revolution is about ten hours, and the time of the revolution of the particles in the outer rim, according to correct calculation, is fifteen hours; and therefore when the lowest parts have revolved thrice the most distant have done so only twice. But however small we may reckon the resistance which the particles offer to each other from their great dispersion in the plane of the ring, it is probable that the lagging behind of the more distant particles at each of their revolutions gradually retards and keeps back the more rapidly moving lower particles; and, on the other hand, these particles must impress on those above them a portion of their motion so as to make them revolve more rapidly. Now if this reciprocal action were not finally interrupted, it would go on till such time as the particles of the ring—both the nearer and the more distant—were brought to revolve in the same time, in which state they would be at rest with respect to each other, and through the revolution they would exert no effect upon each other. But such a condition, if the motion of the ring came to it, would entirely destroy the ring; because if we take the middle of the plane of the ring and suppose that the movement continues there in the state in which it formerly was, and must be, in order to be able to accomplish a free revolution, then the lower particles, owing to their having been much retarded, would not maintain themselves revolving at their height but would cross each other in oblique and eccentric movements, while the more distant particles, by receiving the impetus of a greater motion than that which would correspond to the central force of their distance, would be removed further away from the sun than the solar action which determines the external boundary of the ring; and thereby they could not but be scattered beyond the planet and thus carried away.

But none of this disorder need be feared. The mechanism of the movement generating the ring leads to a determination which, by means of the very causes which might thus destroy it, puts it into a secure state. This comes about by its being divided into a certain number of concentric circular bands which, on account of the intervals that separate them, have no longer any community with each other. For, as the particles which circulate in the inner border of the ring carry forward the further particles by their more rapid motion and accelerate their revolution, so the increased degree of velocity in these particles causes a preponderance of the centrifugal force and the removal of them further from the place where they revolved. But if we suppose that as these particles strive to separate from the nearer particles, they will have to overcome a certain cohesion, which, although that of diffused vapours, yet appears to be not quite insignificant in such cases, then this increased degree of the momentum will tend to overcome the said cohesion. But it will not overcome it as long as the excess of the centripetal power which it exerts in an equal period of revolution with the lowest particles does not exceed the central force of their position or that adhesion among them. And for this reason, in a certain breadth of a band of this ring, although the further particles must exert a tendency to tear themselves away from the lower particles, because its parts perform the revolution in the same time, yet the coherence must subsist but not to a very great breadth. Because, as the velocity of those particles that move in equal times increases with the distances, and therefore more than it should do according to the laws of the central forces, when the velocity has exceeded the degree which the coherence of the vapour particles can offer to it, they must be torn away from the other particles and assume a position at a distance which is conformable to the excess of the centrifugal force over the central force of that place. In this way the interval is determined which separates the first band of the ring from the others; and in like manner the accelerated motion of the more distant particles produced by the rapid revolution of the nearer particles and their coherence which tends to hinder the separation, make the second concentric ring, from which the third is removed by a moderate interval. The number of these circular bands, and the breadth of their intervals, could be calculated if we knew the degree of the cohesion which attaches the particles to each other. But we may be satisfied with having divined generally, and with good grounds of probability, what the nature of the composition of Saturn's ring is which prevents its destruction and keeps it revolving by the free movements of its parts.

This conjecture gives me not a little pleasure from the hope of seeing it yet confirmed by actual observations. Some years ago it was reported from London that in observing Saturn with a new Newtonian telescope improved by Mr. Bradley, it appeared that its ring was properly composed of many concentric rings, which were separated by intervals. This news has not been confirmed by further reports.[1] The optical instruments have opened up for the understanding the means of obtaining knowledge of the furthest regions of the universe. If new progress in this department of knowledge is mainly dependent upon such instruments, the attention which our century gives to all that can enlarge the knowledge of men may well justify us in hoping, with all probability, that it will be turned predominantly to that side of the

[1] Since I made this statement, I find in the *Mémoires* of the Royal Academy of Sciences at Paris, of the year 1705, in a paper by M. Cassini "On the Satellites and Ring of Saturn" (on page 571 of Steinwehr's translation), a confirmation of this conjecture, which leaves almost no doubt of its correctness. M. Cassini begins by suggesting an idea which might be regarded as to some extent an approximation to the truth which we have expounded, although it is improbable in itself: namely, that this ring may perhaps be a swarm of small satellites which would present the same appearance from Saturn as the Milky Way does from the Earth—an idea which may be accepted if we substitute for these small satellites the vapour-particles which revolve around the planet with the same motion. He then proceeds to say: "*This idea is confirmed by the observations which have been made in years when Saturn's ring appeared broader and opener. For the breadth of the ring was seen divided into two parts by a dark elliptical line whose nearest part towards the planet was brighter than the most distant part. This line marked, as it were, a small interval between the two parts of the ring, just as the distance of the globe from the ring is indicated by the greatest extent of the darkness lying between them.*"

subject which offers the greatest prospect of important discoveries.

But if Saturn has been so fortunate as to acquire a ring, why then has no other planet come to participate in this advantage? The reason is clear. Since a ring must arise from the evaporations of a planet which has exhaled them in its crude state, and as its axial rotation must give them the impulsion which they have only to carry on when they have reached that height at which they can just attain to equilibrium with this implanted motion of gravitation towards the planet, it can be easily determined by calculation to what height the vapours of a planet must ascend, if they are to maintain themselves in free circular motion by the movements which they had about its equator, when we know the diameter of the planet, the period of its rotation, and the gravity of bodies at its surface. According to the law of the central motion the distance of a body which can revolve freely in a circle around a planet with a velocity equal to its axial rotation will be in the same ratio to the semi-diameter of the planet as the centrifugal force at its equator is to the gravity. For these reasons the distance of the inner border of Saturn's ring is as 8, if its semi-diameter is taken as 5, which two numbers are in the same ratio as 32 : 20, which, as we have formerly observed, expresses the proportion between the gravity and the centrifugal force at the equator. For the same reasons, if it is supposed that Jupiter were to have a ring produced in this way, its least semi-diameter would exceed the semi-diameter of Jupiter ten times, which would coincide with the distance at which its outmost satellite revolves around it; and hence both from these reasons and because the evaporation of a planet cannot extend so far from it, such a ring is impossible. If any one should desire to know why the earth has got no ring, he will find the answer in the greatness of the semi-diameter which it was necessary for its interior border to have, as this must have been 289 semi-diameters of the earth. In the case of the planets that move more slowly, the production of a ring is still further from possibility. And thus there is no case in which a planet could have acquired a ring in the way we have explained but that of the planet which actually has one; and this is no small confirmation of the credibility of our explanation.

But what makes me almost sure that the ring which surrounds Saturn was not acquired in the general way, nor has been produced by the universal laws of formation which have ruled the whole system of the planets, and which have procured for Saturn his satellites also, is this: that the external matter did not furnish the material for it, but that it is a creation of the planet itself which has sent off its most volatile parts through its heat and has communicated to them by its own axial rotation the impulsion to revolve around it. My conviction is founded on the fact, that the ring is not situated in the general plane of the planetary movements, like its own other satellites, and generally all the revolving bodies which are found accompanying the planets, but its direction deviates considerably from that plane. This is a sure proof that the ring has not been formed from the universal primitive matter, and that it has not acquired its motion from the falling of such matter; but that it has ascended from the planet long after its formation was complete, and that it obtained a motion and direction related to the axial rotation of the planet by the revolving forces implanted in it, as a separated portion of it.[1]

The pleasure of having comprehended and explained one of the rarest peculiarities of the heavens, in the whole extent of its nature and production, has led us to treat it in such detail. Let us, with the favour of our indulgent readers, prosecute the subject wherever it leads in further detail, in order that, having given ourselves up to a pleasant sort of imaginative reflection carried on without any restraint, we may return with the more circumspection and care to truth again.

May it not be imagined that the Earth as well as Saturn once had a ring? This ring would have ascended from its surface just in the same way as that of Saturn, and would maintain itself for a long time, while the Earth would have passed from a much more rapid rotation than

[1] (Oral Statement by Kant in the year 1791.) "The very probable correctness of my theory of the production of this ring from vaporous matter, which kept moving according to central laws, throws at the same time a very favourable light upon the theory of the origin of the great heavenly bodies themselves, according to the same laws—only that their projectile force has been produced by the *fall* of the scattered primitive matter caused by universal gravitation, and not by the axial rotation of the central body. This becomes still more probable if we take into account the further view which was added afterwards as a supplement to the Theory of the Heavens, and which has obtained the important approval of Privy Councillor Lichtenberg, namely, that the primitive vaporous matter diffused through space, which contained in itself all the infinitely varied kinds of matter *in an elastic state*, in forming the heavenly bodies, did it only in this way, that the particles of matter which were endowed with chemical affinity, when, in the course of their fall according to the laws of gravitation, they impinged on each other, mutually destroyed their elasticity, but thereby produced dense masses and brought forth in these that heat, which in the great heavenly bodies (the suns) is combined externally with the property of illumination, and in the lesser bodies (the planets) with internal warmth."

it has at present through certain unknown retarding causes till it reached its present rate of rotation; or, the ring may be supposed to have been formed by the universal primitive material falling obliquely according to the rules which we have already explained—all which must not be taken too rigorously if we are to satisfy our inclination for what is singular. But what an abundance of beautiful explanations and consequences does such an idea furnish! A ring round the earth! What a beautiful sight for those who were created to inhabit the earth as a paradise! What a convenience for those on whom nature was designed to smile on all sides! But all this is still nothing compared with the confirmation which such an hypothesis may borrow from the record of the History of Creation, and which is no small recommendation of it for the approval of those who believe that they do not desecrate, but establish, the honour of revelation when they employ it to give confirmation to the revellings of their own understanding. The water of the firmament, which the Mosaic description mentions, has already caused not a little trouble to commentators. Might this ring not be used to help them out of this difficulty? This ring undoubtedly consisted of watery vapours. And besides the advantage which it might furnish to the first inhabitants of the earth, it had further this property of being able to be broken up on occasion, if need were, to punish the world which had made itself unworthy of such beauty, with a Deluge. Either a comet whose attraction brought the regular movements of its parts into confusion, or the cooling of the region in which it was situated, condensed its scattered vapour-particles, and precipitated them in one of the most awful deluges upon the earth. It is easy to understand what the consequence of this would be. The whole world was submerged under water. And, besides, it sucked in with the foreign and subtle vapours of this unnatural rain, that slow poison which brought all creatures nearer death and destruction. At the same time, the figure of that pale and light bow now disappeared from the horizon; and the new world, which could never recall its appearance without feeling terror before this fearful instrument of Divine vengeance, saw perhaps with no little consternation in the first rain that fell, that coloured bow which seemed by its figure to be a copy of the first, but which through the assurance of Heaven being reconciled, was to be a gracious sign and monument of the continuous preservation of the now altered earth. The resemblance of the form of this memorial sign with the event it indicated, may recommend such an hypothesis to those who are devoted to the prevailing tendency to bring the miracles of Revelation into a system along with the ordinary laws of nature. I find it more advisable to sacrifice the transient approval which such harmonizings may awaken, entirely to the true pleasure which arises from the perception of the regular connection of things, when physical analogies support each other in demonstrating physical truths.

SIXTH CHAPTER.

OF THE ZODIACAL LIGHT.

THE sun is surrounded with a subtle vapour which surrounds it in the plane of its equator, and is spread out to only a small breadth on both sides but extending to a great distance. We cannot be certain whether, as M. de Mairan holds, it comes into contact with the surface of the sun in the figure of a convex glass or lens (*figura lenticulari*), or, like Saturn's ring, is everywhere removed to a distance from it. Whichever of these views is correct, there remains resemblance enough to bring this phenomenon into comparison with Saturn's ring, and to derive it from a similar origin. If this diffused matter is an efflux from the sun, as is most probable, it is not possible to mistake the cause which has brought it into the common plane of the sun's equator. The lightest and most volatile matter, which the fire of the sun raises from its surface and has so raised long ago, is driven by its action far away from it; and, according to the proportion of its lightness, it continues to revolve at the distance at which the propelling action of the rays comes to equilibrium with the gravity of these particles of vapour; or, they are supported by the accession of new particles which are constantly coming to them. Now, because the sun in turning round its axis, impressed its motion equally on these vapours thus detached from its surface, they preserved a certain impetus to a revolving movement, whereby, according to the laws of the central forces, they tended to intersect the prolonged equatorial plane of the sun in the circle in which they move; and hence, because they press to it in equal quantities from both hemispheres, they accumulate there with equal forces and form an expanded plain in the plane of the solar equator.

But, notwithstanding this resemblance with Saturn's ring, there remains an essential distinction which makes the phenomenon of the Zodiacal Light very different from it. The particles of the ring maintain themselves by the movement of rotation implanted in them, in a free circular orbit; but the particles of the Zodiacal Light are maintained at their distance by the force of the sun's rays, without which the motion inherent in them from the rotation of the sun would be quite insufficient to keep them freely revolving and from falling. For, as the centripetal force of the axial rotation on the surface of the sun is not $\frac{1}{40000}$ of the attraction, the ascending vapours would necessarily have to be removed 40,000 semi-diameters from the sun in order to find at that distance just such a gravitation as would produce equilibrium with the motion communicated to them. It is therefore certain that this phenomenon of the sun is not to be assigned to it in the same way as the ring of Saturn is to that planet.

But it is not improbable that this necklace of the sun may be due to the same origin which is exhibited by the whole of nature, as already indicated. It may have been formed out of the universal primitive matter whose particles, when it was floating around in the highest regions of the solar world, only sank to the sun after the completely-finished formation of the whole system, by a late fall with weakened motion, but yet bent from west to east; and by means of this kind of circulation they may have intersected the extended plane of the sun's equator; and by accumulating there on both sides and stopping in that region, they may have occupied an expanded plane in this position, in which, partly through the repulsion of the sun's rays, and partly by the circular motion actually attained by them, they now maintain themselves constantly at the same distance. This explanation has no other value than what may be assigned to an hypothesis; and it makes no claim to more than a favourable consideration. The judgment of the reader on the various views presented may turn to that side which seems to him most deserving of acceptance.

SEVENTH CHAPTER.

OF THE CREATION IN THE WHOLE EXTENT OF ITS INFINITUDE IN SPACE AS WELL AS IN TIME.

THE universe, by its immeasurable greatness and the infinite variety and beauty that shine from it on all sides, fills us with silent wonder. If the presentation of all this perfection moves the imagination, the understanding is seized by another kind of rapture when, from another point of view, it considers how such magnificence and such greatness can flow from a single law, with an eternal and perfect order. The planetary world in which the sun, acting with its powerful attraction from the centre of all the orbits, makes the moving spheres of its system revolve in eternal circles, has been wholly formed, as we have seen, out of the originally diffused primitive stuff that constituted all the matter of the world. All the fixed stars which the eye discovers in the hollow depths of the heavens, and which seem to display a sort of prodigality, are suns and centres of similar systems. Analogy thus does not leave us to doubt that these systems have been formed and produced in the same way as the one in which we find ourselves, namely, out of the smallest particles of the elementary matter that filled empty space—that infinite receptacle of the Divine Presence.

If, then, all the worlds and systems acknowledge the same kind of origin, if attraction is unlimited and universal, while the repulsion of the elements is likewise everywhere active; if, in presence of the infinite, the great and small are small alike; have not all the universes received a relative constitution and systematic connection similar to what the heavenly bodies of our solar world have on the small scale—such as Saturn, Jupiter, and the Earth, which are particular systems by themselves, and yet are connected with each other as members of a still greater system? If in the immeasurable space in which all the suns of the Milky Way have formed themselves, we assume a point around which, through some cause or other, the first formation of nature out of chaos began, there the largest mass and a body of extraordinary attraction will have arisen which has thereby become capable of compelling all the systems in the process of being formed within an enormous sphere around it, to fall towards itself as their centre, and to build up a system around it on the great scale similar to that which the elementary matter that formed the planets has constructed in the small scale around the sun. Observation puts this conjecture almost beyond doubt. The host of the stars, by their relative positions towards a common plane, constitute a system just as much as do the planets of our Solar System around the sun. The Milky Way is the Zodiac of those higher worlds, which diverge as little as possible from its zone and whose strip of space is always illuminated by their light, just as the zodiac of the planets always glitters here and there although only in a few points with the splendour of these spheres. Every one of these suns, with its revolving planets, constitutes a particular system by itself; but this does not hinder them from being parts of a still greater system, just as Jupiter or Saturn, notwithstanding their being accompanied by satellites of their own, are embraced in the systematic constitution of a still greater system. With such an exact agreement in their constitution, can we not recognize the same cause and mode of production in them?

If, then, the fixed stars constitute a system whose extent is determined by the sphere of the attraction of that body which is situated in the centre, shall there not have arisen more Solar Systems and, so to speak, more Milky Ways, which have been produced in the boundless field of space? We have beheld with astonishment figures in the heavens which are nothing else than such systems of fixed stars confined to a common plane—Milky Ways, if I may so express myself, which, in their different positions to the eye, present elliptical forms with a glimmer that is weakened in proportion to their infinite distance. They are systems of, so to speak, an infinite number of times infinitely greater diameter than the diameter of the Solar System. But undoubtedly they have arisen in the same way, have been arranged and regulated by the same causes, and preserve themselves in their constitution by a mechanism similar to that which rules our own system.

If, again, these star-systems are viewed as members in the great chain of the totality of nature, then there is just as much reason as formerly to think of them as in mutual relation and in connections which, in virtue of the law of their primary formation that rules the whole of nature, constitute a new and greater system ruled by the attraction of a body of incomparably mightier attraction, and acting from the centre of their regulated positions. The attraction which is the cause of the systematic constitution among the fixed stars of the Milky Way acts also at the distance even of those worlds, so that it would draw them out of their positions and bury the world in an inevitably impending chaos, unless the regularly distributed forces of rotation formed a counterpoise or equilibrium with attraction, and mutually produced in combination that connection which is the foundation of the systematic constitution. Attraction is undoubtedly a property of matter extending as far as that co-existence which constitutes space, seeing that it combines substances by their mutual dependence; or, to speak more exactly, attraction is just that universal relation which unites the parts of nature in one space. It reaches, therefore, to the whole extent of space, even to all the distance of nature's infinitude. If light reaches us from these distant systems—light which is only an impressed motion—must not attraction, that original source of motion, which is prior to all motion, which needs no foreign cause and can be stopped by no obstacles, because it penetrates into the inmost recesses of matter without any impact even in the universal repose of nature; must not, I say, attraction have put those fixed star-systems, notwithstanding their immense distances, into motion when nature began to stir through the unformed dispersion of her material? And as we have seen on the small scale, is not this attraction the source of the systematic combination and the lasting persistence of the members of these systems, and that which secures them from falling to pieces?

But what is at last the end of these systematic arrangements? Where shall creation itself cease? It is evident that in order to think of it as in proportion to the power of the Infinite Being, it must have no limits at all. We come no nearer the infinitude of the creative power of God, if we enclose the space of its revelation within a sphere described with the radius of the Milky Way, than if we were to limit it to a ball an inch in diameter. All that is finite, whatever has limits and a definite relation to unity, is equally far removed from the infinite. Now, it would be absurd to represent the Deity as passing into action with an infinitely small part of His potency, and to think of His Infinite Power—the storehouse of a true immensity of natures and worlds—as inactive, and as shut up eternally in a state of not being exercised. Is it not much more reasonable, or, to say it better, is it not *necessary* to represent the system of creation as it must be in order to be a witness of that power which cannot be measured by any standard? For this reason the field of the revelation of the Divine attributes is as infinite as these attributes themselves.[1] Eternity is not sufficient to

[1] The conception of an infinite extension of the world finds opponents among the metaphysicians, and has lately found one in M. Weitenkampf. If these gentlemen, on account of the supposed impossibility of a quantity without number and limits, cannot accommodate themselves to this idea, I would only ask in the meantime the question: Whether the future succession of Eternity will not embrace in it a true infinitude of multiplicities and changes, and whether this infinite series is not now already wholly present at once to the Divine intelligence? Now, if it was possible that God could make the conception of the infinitude which presents itself at once to His understanding, real in a series of facts following each other in succession, why should He not be able to exhibit the conception of another infinitude in a *combined connection* in space, and thereby make the extension of the world without limits? While any one is trying to answer this question, I will use the opportunity which may be furnished, to remove the supposed difficulty by an elucidation drawn from the

embrace the manifestations of the Supreme Being, if it is not combined with the infinitude of space. It is true that development, form, beauty, and perfection are relations of the elements and the substances that constitute the matter of the universe, and this is perceived in the arrangements which the wisdom of God adopts at all times. It is also most conformable to that wisdom that these relations and arrangements should be evolved out of their implanted universal laws by an unconstrained consecution. And hence it may be laid down, with good reason, that the arrangement and institution of the universe comes about gradually, as it arises out of the provision of the created matter of nature in the sequence of time. But the primitive matter itself, whose qualities and forces lie at the basis of all changes, is an immediate consequence of the Divine existence; and that same matter must therefore be at once so rich and so complete, that the development of its combinations in the flow of eternity may extend over a plane which includes in itself all that can be, which accepts no limit, and, in short, which is infinite.

If, therefore, the creation is infinite in space, or at least has really been so in its matter from the beginning, and is ready to become so in form or development, then the whole of space will be animated with worlds without number and without end. Will then that Systematic Connection, which we have already considered in particular in regard to all the parts of the world, extend to the

nature of numbers, in so far as, on careful consideration, it may still be regarded as a question requiring explanation. And so I ask, whether that which a higher Power, accompanied with the highest wisdom, *has produced* in order to reveal itself, does not stand in the relation of a *differential* quantity to that which it *was able to produce*?

whole and embrace the whole universe, the totality of nature in a single system, by the connecting power of attraction and centrifugal force? I say, Yes. If there existed only isolated systems which had no unified connection into a whole with one another, it might be imagined—were this chain of members assumed to be really infinite—that an exact equality in the attraction of their parts from all sides, could keep these systems secure from the destruction with which their inner mutual attraction threatens them. But this would evolve such an exact measured determination at the distance proportionate to the attraction, that even the slightest displacement would draw the ruin of the universe along with it; and after long periods, which, however, must finally come to an end, it would give it up to utter overthrow. A constitution of the world which did not maintain itself without a miracle, has not the character of that stability which is the mark of the choice of God. It is therefore much more in conformity with that choice to make the whole creation a single system which puts all the worlds and systems of worlds, that fill the whole of infinite space, into relation to a single centre. A scattered swarm of systems, however—for they might be separated from each other—would, by an unchecked tendency, hurry to disorder and destruction, unless a certain relative disposition were made by reference to a universal centre, the centre of the attraction of the universe, and unless means were taken for the maintenance of the whole of nature by systematic motions.

This universal centre of the attraction of the whole of nature, both in its crude and formed state, is the point at which is undoubtedly situated the mass of the most powerful attraction which embraces within the sphere of its attraction all the worlds and systems which time has produced, and which Eternity will produce; and it may with probability be assumed that around it nature made the beginning of its formation, and that the systems are accumulated most closely there, whereas further from that point, in the infinitude of space, they will disappear more and more with greater and greater degrees of dispersion. This law might be deduced from the analogy of our Solar System; and such a constitution may moreover serve this purpose, that at great distances not only the universal central body, but all the systems that revolve next round it, may combine their attraction and exercise it as if from one mass upon the systems which are at a still greater distance. This arrangement would then be subservient to embracing the whole of nature in all the infinitude of its extension in a single system.

Let us now proceed to trace out the construction of this Universal System of Nature from the mechanical laws of matter striving to form it. In the infinite space of the scattered elementary matter there must have been some one place where this primitive material had been most densely accumulated so as through the process of formation that was going on predominantly there, to have procured for the whole Universe a mass which might serve as its fulcrum. It indeed holds true that in an infinite space no point can properly have the privilege to be called the centre; but by means of a certain ratio, which is founded upon the essential degrees of the density of the primitive matter, according to which at its creation it is accumulated more densely in a certain place and increases in its dispersion with the distance from it, such a point may have the privilege of being called the centre; and it really becomes this through the formation of the central mass by the strongest attraction prevailing in it. To this point all the rest of the elementary matter engaged in particular formations is attracted; and, thereby, so far as the evolution of nature may extend it makes in the infinite sphere of the creation the whole universe into only one single system.

But it is important, and, if approved, is deserving of the greatest attention, that in consequence of the order of nature in this our system, the creation, or rather the development of nature, first begins at this centre and, constantly advancing, it gradually becomes extended into all the remoter regions, in order to fill up infinite space in the progress of eternity with worlds and systems. Let us dwell upon this idea for a moment with the silent satisfaction it brings. I find nothing which can raise the spirit of man to a nobler wonder, by opening to him a prospect into the infinite domain of omnipotence, than that part of my theory which concerns the successive realization of the creation. If it is admitted that the matter, which is the stuff for the formation of all the world, was not uniform in the whole infinite space to which God is present, but was spread out according to a certain law, perhaps proportioned to the density of the particles, and according to which the dispersion of the primitive matter increased from a certain point, as the place of densest accumulation, with the distance from this centre; then at the primary stirring of nature, formation will have begun nearest this centre; and in advancing succession of time the more distant regions of space will have gradually formed worlds and systems with a systematic constitution related to that centre. Every finite period, whose duration has a proportion to the greatness of the work to be accomplished, will always bring only a finite sphere to its development from this centre; while the remaining infinite part will still be in conflict with the confusion and chaos, and will be the further from the state of completed formation the farther its distance is away from the sphere of the already developed part of nature. In consequence of this, although from the place of our abode in the Universe, we look out upon a world wholly completed as it seems, and, so to speak, at an infinite host of worlds which are systematically combined; yet, strictly speaking, we find ourselves only in the neighbourhood of the centre of the whole of nature, where it has already evolved itself out of chaos and attained its proper perfection. If we could overstep a certain sphere we would there perceive chaos and the dispersion of the elements which, in the proportion in which they are found nearer this centre, lose in part their crude state and are nearer the perfection of their development, but in the degree in which they are removed from the centre, they are gradually lost in a complete dispersion. We would see how the infinite space, co-extensive with the Divine Presence, in which is to be found the provision for all possible natural formations, buried in a silent night, is full of matter which has to serve as material for the worlds that are to be produced in the future, and of impulses for bringing it into motion, which begin with a weak stirring of those movements with which the immensity of these desert spaces are yet to be animated. There had mayhap flown past a series of millions of years and centuries, before the sphere of the formed nature in which we find ourselves, attained to the perfection which is now embodied in it; and perhaps as long a period will pass before Nature will take another step as far in chaos. But the sphere of developed nature is incessantly engaged in extending itself. Creation is not the work of a moment. When it has once made a beginning with the production of an infinity of substances and matter, it continues in operation through the whole succession of eternity with ever increasing degrees of fruitfulness. Millions and whole myriads of millions of centuries will flow on, during which always new worlds and systems of worlds will be formed after each other in the distant regions away from the centre of nature, and will attain to perfection. Notwithstanding the Systematic Constitution embodied in their parts, they will obtain a universal relation to the centre which has become the first formative point and the centre of the creation, through the attractive power of its predominant mass. This infinity in the future succession of time, by which eternity is unexhausted, will entirely animate the whole range of space to which God is present, and will gradually put it into that regular order which is conformable to the excellence of His plan. And if we could embrace the whole of eternity with a bold grasp, so to speak, in one conception, we would also be able to see the whole of infinite space filled with systems of worlds and the creation all complete. But as, in fact, the remaining part of the succession of eternity is always infinite and that which has flowed is finite, the sphere of developed nature is always but an infinitely small part of that totality which has the seed of future worlds in itself, and which strives to evolve itself out of the crude state of chaos through longer or shorter periods. The creation is never finished or complete. It has indeed once begun, but it will never cease. It is always busy producing new scenes of nature, new objects, and new worlds. The work which it brings about has a relationship to the time which it expends upon it. It needs nothing less than an eternity to animate the whole boundless range of the infinite extension of space with worlds, without number and without end. We may say of it what the sublimest of the German poets writes of Eternity:

> "Infinity! What measures thee?
> Before thee worlds as days, and men as moments flee!
> Mayhap the thousandth sun is rounding now;
> And thousands still remain behind!
> Even as the clock its weight doth wind,
> A sun by God's own power is driven;
> And when its work is done, again in heaven
> Another shines. But thou remain'st! To thee all numbers bow."
>
> VON HALLER.

It is not a small pleasure to sweep in imagination beyond the boundary of the completed creation into the region of chaos, and to see the half crude nature in the neighbourhood of the sphere of the developed world losing itself gradually through all stages and shades of imperfection, throughout the whole range of unformed space. But it will be said: Is it not a reprehensible boldness to put forward an hypothesis, and to laud it as a subject for the entertainment of the understanding, which, perhaps, is only too arbitrary when it is asserted that nature is developed only in an infinitely small part, and that endless ranges of space are still involved in a conflict with chaos in order to bring forth through the succession of future ages whole hosts of worlds and systems, and to present them in all their proper order and beauty? I am not so devoted to the consequences of my theory that I should not be ready to acknowledge that the supposition of the successive expansion of the creation through the infinite regions of space which contain the matter for it, cannot entirely escape the reproach of its being undemonstrable. Nevertheless, I expect from those who are capable of estimating degrees of probability that such a chart of the infinite, comprehending, as it does, a subject which seems to be destined to be for ever concealed from the human understanding, will not on that account be at once regarded as a chimera, especially when recourse is had to analogy, which must always guide us in those cases in which the understanding cannot follow the thread of infallible demonstrations.

This analogy may, however, be supported by other tenable reasons; and the perspicuity of the reader, so far as I may flatter myself with his favourable consideration, will perhaps be able to increase them by adding other reasons more powerful still. For if it is considered that creation does not bring the character of stability with it, in so far as it does not oppose to the universal striving of attraction which acts through all its parts, as thorough a determination sufficient to resist the tendency of the former to destruction and disorder; if it has not distributed forces of impulsion which, in combination with the central tendency, establish a universal Systematic Constitution: then we are forced to a universal centre of the whole universe which holds all its parts together in a combined connection, and makes the totality of nature into only one system. If to this we add the conception of the formation of the world-bodies from the scattered elementary matter, as has been delineated above, yet do not limit it here to a separate system but extend it to the whole of nature: we shall be compelled to think of such a distribution of the primitive matter in the space of the original chaos, as bringing with it naturally a centre of the whole creation in order that the active mass, which embraces the whole of nature within its sphere, may be concentrated at this point, and that a thoroughgoing combination may be effected, by which all the worlds shall constitute only one single structure. But in the infinite space, another mode of distribution of the original material, which could posit a true centre and attracting point for the whole of nature, could hardly be conceived other than the one according to which it is arranged to all remote distances by a law of increasing dispersion from that point. But this law, moreover, involves a difference in the time which a system needs in the different regions of infinite space for the maturing of its development, so that this period is found the shorter the nearer the place of the formation of a world is found to the centre of creation, because the elements of matter are more densely accumulated there; and, on the other hand, longer time will be required the greater the distance is, because the particles are more dispersed there, and unite for formation later on.

If the whole hypothesis which I have sketched is examined in the extent of all I have said, as well as of what I shall still specially present, the boldness of its demands on the reader should at least not be regarded as being beyond excuse. The inevitable tendency which every world that has been brought to completion gradually shows towards its destruction, may even be reckoned among the reasons which may establish the fact that the universe will again be fruitful of worlds in other regions to compensate for the loss which it has suffered in any one place. The whole portion of nature which we know, although it is only an atom in comparison with what remains concealed above or below our horizon, establishes at least this fruitfulness of nature, which is unlimited, because it is nothing else than the exercise of the Divine omnipotence. Innumerable animals and plants are daily destroyed and disappear as the victims of time; but not the less does nature by her unexhausted power of reproduction, bring forth others in other places to fill up the void. Considerable portions of the earth which we inhabit are being buried again in the sea, from which a favourable period had drawn them forth; but at other places nature repairs the loss and brings forth other regions which were hidden in the depths of being in order to spread over them the new wealth of her fertility. In the same way worlds and systems perish and are swallowed up in the abyss of eternity; but at the same time creation is always busy constructing new formations in the heavens, and advantageously making up for the loss.

We need not be astonished at finding a certain transitoriness even in the greatest of the works of God. All that is finite, whatever has a beginning and origin, has the mark of its limited nature in itself; it must perish and have an end. The duration of a world has, by the excellence of its construction, a certain stability in itself which, according to our conceptions, approaches an endless duration. Perhaps thousands, mayhap millions, of centuries will not destroy it; but because the vanity which cleaves to finite natures works constantly for their destruction, eternity will contain in itself all the possible periods required to bring about at last by gradual decay the moment when the world shall perish. Newton, that great admirer of the attributes of God from the perfection of

His works, who combined with the deepest insight into the excellence of nature the greatest reverence for the revelation of the Divine omnipotence, saw himself compelled to predict the decay of nature by the natural tendency which the mechanics of motion has to it. If a Systematic Constitution, by the inherent consequence of its perishableness through great periods, brings even the very smallest part which can be imagined nigh to the state of disorder, there must be a moment in the infinite course of eternity at which this gradual diminution will have exhausted all motion.

But we ought not to lament the perishing of a world as a real loss of Nature. She proves her riches by a sort of prodigality which, while certain parts pay their tribute to mortality, maintains itself unimpaired by numberless new generations in the whole range of its perfection. What an innumerable multitude of flowers and insects are destroyed by a single cold day! And how little are they missed, although they are glorious products of the art of nature and demonstrations of the Divine Omnipotence! In another place, however, this loss is again compensated for to superabundance. Man who seems to be the masterpiece of the creation, is himself not excepted from this law. Nature proves that she is quite as rich and quite as inexhaustible in the production of what is most excellent among the creatures, as of what is most trivial, and that even their destruction is a necessary shading amid the multiplicity of her suns, because their production costs her nothing. The injurious influences of infected air, earthquakes, and inundations sweep whole peoples from the earth; but it does not appear that nature has thereby suffered any damage. In the same way whole worlds and systems quit the stage of the universe, after they have played out their parts. The infinitude of the creation is great enough to make a world, or a Milky Way of worlds, look in comparison with it, what a flower or an insect does in comparison with the earth. But while nature thus adorns eternity with changing scenes, God continues engaged in incessant creation in forming the matter for the construction of still greater worlds.

> "He sees with equal eye, as God of all,
> A hero perish, or a sparrow fall;
> Atoms or systems into ruin hurl'd,
> And now a bubble burst, and now a world."
>
> POPE.

Let us then accustom our eye to these terrible catastrophes as being the common ways of providence, and regard them even with a sort of complacency. And in fact nothing is more befitting the riches of nature than such an attitude towards her. For when a world-system in the long succession of its duration exhausts all the manifold variation which its structure can embrace; when it has at last become a superfluous member in the chain of beings; there is nothing more becoming than that it should play the last part in the drama of the closing changes of the universe, a part which belongs to every finite thing, namely, that it should pay its tribute to mortality. Nature—as has been said—already shows in the smallest part of her system that rule of procedure which eternal fate has prescribed to her on the whole. And, I say it again, the greatness of what has to perish, is not the least obstacle to it; for all that is great becomes small, nay, it becomes as it were a mere point, when it is compared with the Infinitude which creation has to exhibit in unlimited space throughout the succession of eternity.

It seems that this end which is to be the fate of the worlds, as of all natural things, is subject to a certain law whose consideration gives our theory a new feature to recommend it. According to that law the heavenly bodies that perish first, are those which are situated nearest the centre of the universe, even as production and formation did begin near this centre; and from that region deterioration and destruction gradually spread to further distances till they come to bury all the world that has finished its period, through a gradual decline of its movements, in a single chaos at last. On the other hand, Nature unceasingly occupies herself at the opposite boundary of the developed world, in forming worlds out of the raw material of the scattered elements; and thus, while she grows old on one side near the centre, she is young on the other, and is fruitful in new productions. According to this law the developed world is bounded in the middle between the ruins of the nature that has been destroyed and the chaos of the nature that is still unformed; and if we suppose, as is probable, that a world which has already attained to perfection may last a longer time than what it required to become formed, then, notwithstanding all the devastations which the perishableness of things incessantly brings about, the range of the universe will still generally increase.

But, finally, when admission is given to another idea which is just as probably in accordance with the constitution of the Divine works, the satisfaction which such a delineation of the changes of nature excites, is raised to the highest degree of complacency. Can we not believe that Nature, which was capable of developing herself out of chaos into a regular order and into an arranged system, is likewise capable of re-arranging herself again as easily out of the new chaos into which the diminution of her motions has plunged her, and to renew the former combination? Cannot the springs which put the stuff of the dispersed matter into motion and order, after the stopping of the machine has brought them to rest, be again put into action by extended forces; and may they not by the same general laws limit each other until they attain that harmony by which the original formation was brought about? It will not need long reflection to admit this, when it is considered that after the final exhaustion of the revolving movements in the universe has precipitated all the planets and comets together into the sun, its glowing heat must obtain an immense increase by the commingling of so many and so great masses; especially as the distant globes of the Solar System, in consequence of the theory already expounded, contain in themselves the lightest matter in all nature, and that which is most active on fire. This fire, thus put by new nourishment and the most volatile matter into the most violent conflagration, will undoubtedly not only resolve everything again into the smallest elements, but will also disperse and scatter these elements again in this way with a power of expansion proportional to the heat, and with a rapidity which is not weakened by any resistance in the intervening space; and they will thus be dissipated into the same wide regions of space which they had occupied before the first formation of nature. The result of this will be that, after the violence of the central fire has been subdued by an almost total dispersion of its mass, the forces of attraction and repulsion will again combine to repeat the old creations and the systematically connected movements, with not less regularity than before, and to present a new universe. If, then, a particular planetary system has fallen to pieces in this way, and has again restored itself by its essential forces, nay, when it has even repeated this play more than once, then at last the period will approach which will gather in the same way the great system of which the fixed stars are members into one chaos through the falling of their movements. Here it will still less be doubted that the reunion of such an infinite multitude of masses of fire as these burning suns are, together with the train of their planets, will disperse the matter of their masses when dissolved by the ensuing unspeakable heat into the old space of their sphere of formation, and will there furnish materials for new productions by the same mechanical laws, whereby the waste space will again be animated with worlds and systems. When we follow this Phoenix of nature, which burns itself only in order to revive again in restored youth from its ashes, through all the infinity of times and spaces; when it is seen how nature, even in the region where it decays and grows old, advances unexhausted through new scenes, and, at the other boundary of creation in the space of the unformed crude matter, moves on with steady steps, carrying on the plan of the Divine revelation, in order to fill eternity, as well as all the regions of space, with her wonders: then the spirit which meditates upon all this sinks into profound astonishment. But unsatisfied even yet with this immense object, whose transitoriness cannot adequately satisfy the soul, the mind wishes to obtain a closer knowledge of that Being whose Intelligence and Greatness is the source of that light which is diffused over the whole of nature, as it were, from one centre. With what reverence must not the soul regard even its own being, when it considers that it is destined to survive all these transformations! It may well say to itself what the philosophic poet says of Eternity:

> "And when the World shall sink, and Nothing be once more,
> When but its place remains, and all else is consumed;
> And many another heaven, by other stars illumed,
> Shall vanish when its course is o'er:
> Yet thou shalt be as far as ever from thy death,
> And as to-day thou then shalt breathe eternal breath."
>
> VON HALLER.

Oh! happy will be the soul if, amid the tumult of the elements and the crash of nature, she is always elevated to a height from whence she can see the devastations which their own perishableness brings upon the things of the world as they thunder past beneath her feet. This happiness, which Reason of herself could not be bold enough even to aspire to, Revelation teaches us to hope for with full conviction. When the fetters which keep us bound to the vanity of the creatures, have fallen away at the moment which has been destined for the transformation of our being, then will the immortal spirit be liberated from dependence on finite things, and find in fellowship with the Infinite Being the enjoyment of its true felicity. All nature, which involves a universal harmonious relation to the self-satisfaction of the Deity, cannot but fill the rational creature with an everlasting satisfaction, when it finds itself united with this Primary Source of all perfection. Nature, seen from this centre, will show on all sides utter security, complete adaptation. The changeful scenes of the natural world will not be able to disturb the restful happiness of a spirit which has once been raised to such a height. And while it already tastes beforehand this blessed state with a sweet hopefulness, it may at the same time utter itself in those songs of praise with which all eternity shall yet resound.

"When Nature fails, and day and night
Divide Thy works no more,
My ever grateful heart, O Lord,
Thy mercy shall adore.

"Through all Eternity to Thee
A joyful song I'll raise;
For, oh! Eternity's too short
To utter all Thy praise."

ADDISON.

ADDITION TO THE SEVENTH CHAPTER.

A GENERAL THEORY AND HISTORY OF THE SUN.

THERE is another important question, the solution of which is indispensable in a physical theory of the heavens and in a complete cosmogony. It is this: Why is it that the centre of every system is occupied by a flaming body? Our Planetary System has the sun as its central body, and the fixed stars which we see are, in all probability, centres of similar systems.

In order to understand how it comes about that, in the formation of a cosmic system, the body which serves as the centre of attraction must have become a fiery body, notwithstanding that the other globes within the sphere of its attraction remained dark and cold bodies, we have only to recall the mode in which a cosmic system is produced. This has been sketched circumstantially in the preceding pages. In the widely extended space in which the diffused elementary matter adapts itself into formations and systematic motions, the planets and comets are formed only from that portion of the elementary matter that sinks to the centre of attraction, and which has been determined by the fall and the reciprocal action of the whole of the particles, to that delimitation of their direction and velocity which is required for their revolution. This portion of the primitive matter, as has been already shown, is the least condensed of the whole mass of the obliquely sinking matter, and is, indeed, only the remainder of the denser kinds of matter which have been able to attain that degree of exactness in their motions through the resistance of other kinds of matter. In this mixture there are found floating kinds of matter of predominant lightness, which, being impeded by the resistance of space, do not by their fall attain to the proper rapidity of the periodic revolutions, and which, in consequence of the feebleness of their impulsion, are wholly thrown down to the central body. And because these lighter and volatile portions are also the most active in maintaining fire, we see that, by their accession, the body which is the centre of the system thus obtains the advantage of becoming a flaming ball, or, in a word, becomes a sun. On the other hand, the heavier and more inert matter, and the want of these fire-supporting particles, make the planets only cold and dead masses, destitute of this property of the flaming sun.

This accession of such light materials is also the reason why the sun has obtained its specifically lower density, by which it is four times less dense than even our earth, which is the third planet in distance from it. Yet it is natural to think that in this centre of the system, as in its lowest place, the heaviest and densest kinds of matter should be found, and that thereby, without the addition of so great a mass of the lightest matter, it would yet surpass the density of all the planets.

The mixture of denser and heavier kinds of elements with these lightest and most volatile particles serves likewise to make the central body fitted for bearing the most violent glow of heat that may be burned and maintained on its surface. For we know that a fire in whose supply of matter dense materials are found mixed with those that are volatile, is greater in violence than that flame which is maintained only by the light kinds of matter. But this mingling of certain heavy kinds of matter with lighter kinds is a necessary consequence of our theory of the formation of the cosmic bodies; and it has besides this advantage, that the force of the conflagration does not suddenly scatter the combustible matter found on the surface, and that the conflagration is gradually and constantly supported by the accession of nourishment from the interior.

The question having now been solved as to why the central body of a great stellar system is a flaming ball, *i.e.* a sun, it appears to be not superfluous to consider this subject somewhat further, and to proceed to examine the state of such a celestial body by careful investigation. This is the more incumbent, as the conjectures we may form can be founded here on more solid reasons than is commonly the case in investigations concerning the condition of distant celestial bodies.

And, in the first place, I lay it down that it cannot be doubted that the sun really *is* a flaming body, and not a mass of molten and glowing matter heated up to the highest degree, as some have maintained on account of certain difficulties which they suppose to be found in the former view. For a flaming fire has this essential advantage over every other kind of heat, that it is, so to speak, self-active; and instead of being diminished or exhausted by its communication, on the contrary, it acquires thereby more strength and violence, and therefore requires only material and nourishment for its maintenance to go on continually. On the other hand, the incandescence of a mass heated up to the highest degree is in a merely passive state, which is unceasingly diminished by the contact of the matter connected with it, and has no force of its own by which it could extend itself from a small beginning, nor could it revive again when it has been lowered and lessened. When this is taken into account —not to mention other reasons—it will be already sufficiently seen that the flaming state must be attributed, in all probability, to the sun, which is the source of light and heat in every cosmic system.

Now, if the sun, or the suns generally, are flaming balls, then the first thing determinable regarding their surface, and that can be deduced from this result, is that there must be air found on them, because no fire burns without air. This circumstance leads us to certain remarkable consequences. For, first, if the atmosphere of the sun and its weight is considered in relation to the mass of the sun: in what state of compression will not this air be, and how capable will it not thereby become of maintaining the most violent degrees of fire by its elasticity? In all probability there rise up in this atmosphere clouds of smoke from the materials that are consumed by the flame, and which, as cannot be doubted, have in them a mixture of coarse and lighter particles; and after they have ascended to an elevation which contains what is relatively to them a cooler atmosphere, they are then precipitated in heavy showers of pitch and sulphur, and thus bring new nourishment to the flame. Nor is this atmosphere, from the same causes as operate on our earth, kept free from the motions of winds, which, however, must in all probability far surpass in violence all that our imagination can even conceive. When any region on the surface of the sun, either by the suffocating violence of the bursting vapours, or the scanty supply of combustible material, is less active and lags behind, as it were, at the outburst of the flame, then the atmosphere that is above it becomes somewhat cooled, and contracting it gives place to the air in its neighbourhood, which then presses into the space it occupied with a force proportional to the excess of its elasticity, and it will thereby kindle up the extinguished flame.

Nevertheless, all flame always consumes much air; and there is no doubt that the elastic force of the fluid atmosphere which surrounds the sun must thus undergo no small diminution in time. If we apply here on the great scale the result which Mr. Hales has verified by careful investigations regarding the action of flame in our atmosphere, then the constant operation of the smoke particles that proceed from the flame, by destroying the elasticity of the atmosphere of the sun, presents a great problem, the solution of which is very difficult. For as the flame which burns over the whole surface of the sun uses up the air which is indispensable to it for burning, thereby the sun is in danger of even being extinguished when the most part of its atmosphere has been consumed. It is true that the fire also generates air by the decomposition of certain kinds of matter; but experiments prove that there is always more consumed than generated. In fact, when a part of the fire of the sun is robbed of the air which ministers to its maintenance by suffocating vapours, as we have already remarked, violent storms will then scatter them, and will exert their energy in carrying them away. But, on the whole, the replacing of this necessary element may be made conceivable, if it is considered that, as in a flaming fire, the heat acts almost solely above it, and but little below it; and so when it has been suffocated by the cause referred to, its violence turns towards the interior of the body of the sun and compels its deep abysses to allow the air confined in their cavities to break forth and to kindle the fire anew. And, if we may use a freedom of conjecture, which is not forbidden in connection with such an unknown subject, we may suppose that in the bowels of the sun there are many substances which, like saltpetre, are inexhaustible in yielding elastic air, and thus the fire of the sun may be able to go on through very long periods without suffering in any considerable way from want of the accession of always renewed air.

Nevertheless, distinct marks of transitoriness are to be seen even on this immeasurable fire, which nature has lighted to be the torch of the world. There is a time coming when it will come to be extinguished. The withdrawal of the most volatile and rare materials which, when dispersed by the violence of the heat, never return again, but increase the matter of the Zodiacal Light; the accumulation of incombustible or burned-out material, such as ashes on the surface; and, lastly, the want of air, will put an end to the sun. Then its flame will be extinguished, and eternal darkness will occupy the place which is now the centre of light and life to the whole world. The intermittent efforts of its fire to revive again through breaking open new chasms, by which it will perhaps restore itself several times before its final disappearance, might furnish an explanation of the vanishing and reappearing of some of the fixed stars. These may be regarded as suns which are near their extinction, and which still strive at times to revive out of their ashes. Whether this explanation merits approval or not, yet the view may certainly be admitted so far as it serves to show that, as an inevitable decay threatens the perfection of all the world-formations in one way or another, no difficulty will be found in explaining the above stated law of their destruction by the mere tendency of their mechanical constitution. And it becomes especially deserving of acceptance, because it brings with it the germs of a renovation, even when they are mixed and confounded with chaos.

Lastly, let us now bring near, as it were, to the imagination such a marvellous object as a burning sun is. At a glance we see vast seas of fire which raise their flames to the sky; raging tempests whose fury doubles the violence of the flaming seas, and makes them swell and overflow their shores, till they now cover the elevated regions of the solar body, and again make them sink back into their bounds; charred rocks which stretch their fearful peaks up out of the flaming abysses, and which, when flooded or exposed by the waves of fire, cause the alternating appearance and disappearance of the sun spots; dense vapours which suffocate the fire, and which, lifted by the violence of the winds, produce dark clouds which plunge down again in sheets of raining fire, and then pour themselves as burning rivers from the heights of the solar land into flaming valleys. And all this accompanied with the crashing of the elements, the downrush of burned-out matter, and nature the while struggling with the power of destruction amid the awful horrors of her overthrow, yet working out the beauty of the world and the utility of the creatures.[1]

Now, if the centres of all great world systems are flaming bodies, this is most of all to be supposed of the central body of that enormous system which is constituted by the fixed stars. But if that body, whose mass must have a proportion relative to the size of its system,

[1] Not without cause do I ascribe to the sun all the inequalities of the solid land, mountains, and valleys, such as we encounter on our own earth and other planetary bodies. The formation of a celestial globe, as it changes from a fluid to a solid state, necessarily brings about such inequalities upon its surface. When the surface hardens, the materials in the internal fluid portion of the mass are still sinking, in the ratio of their gravity, to the centre; and the particles of elastic air or fire which are found mingled with these particles are expelled, and they accumulate under the meanwhile solidified crust, beneath which they produce immense cavities, proportional to the mass of the sun. Into these cavities the said crust falls with many folds, and thereby are produced not only elevated regions and mountains, but also valleys and the beds of vast seas of fire.

be a self-luminous body or a sun, will it not strike all eyes as of pre-eminent splendour and greatness? But we do not see any such fixed star so exceptionally distinguishing itself now glittering among the host of heaven. In fact, it need not astonish us if the case is so. Although it surpassed our sun in size ten thousand times, yet if its distance were a hundred times greater than that of Sirius, it would not appear greater and brighter than that star.

But perhaps it is reserved for future times to discover hereafter the region at least where is to be found the centre of the system of the fixed stars to which our sun belongs, or perhaps to determine exactly where the central body of the universe must be located, and towards which all the parts of the universe agree in tending with congruent motion.[1] We shall leave it to Mr. Wright of

[1] I have a conjecture, and it seems to me to be very probable, that Sirius, or the Dog Star, is the central body of the stars that make up the Milky Way, and that it occupies the centre with which they are all in relation. This system, as sketched in the first part of this treatise, may be regarded as a swarm of suns accumulated in a common plane, and dispersed on all sides from their centre through a certain circular space formed by their small deviations from the said plane, and spread out somewhat on both sides. Thus viewed, the sun, being situated near this plane, will see the appearance of that circular zone as a glimmering white light, extended in breadth most on that side on which it is placed nearest the outmost boundary of the system; for it is easy to suppose that it will not be found exactly in the centre. Now, the zone of the Milky Way is broadest in the part that lies between the constellations of the Swan and Sagittarius, and consequently this will be the side where the place of our sun is nearest the outmost periphery of the circular system; and in this part of it we must hold the nearest place to be that where the constellations of the Eagle and Fox and Goose are situated, because at the interval where the Milky Way bifurcates, the greatest visible dispersion of stars is perceived. If, therefore, we draw a line from a spot near the tail of the Eagle through the plane of the Milky Way to the

Durham to determine what is the nature of this foundation stone of the whole creation, and what is to be found upon it. With a fanatical enthusiasm he finds there a powerful Being of a divine nature possessed of spiritual powers of attraction and repulsion which, acting in an infinite sphere around itself, draws to it all virtue, but repels the vices; and in this happy place it is exalted, as it were, to the throne of all nature. We shall, however, not throw the reins of imagination over to the boldness of conjecture—to which we have perhaps only allowed too much already—lest we be carried away by arbitrary fancies.

The Deity is equally present everywhere in the infinitude of the whole of space; He is found equally near wherever there are natures that are capable of soaring above the dependence of the creatures to communion with Him as the supreme Being. The whole creation is penetrated by His energy; but only he who is able to liberate himself from the creature, and who is noble enough to see that the highest reach of happiness can alone be sought in the enjoyment of this primary source of perfection,—he alone is able to find himself nearer to this true attracting-point of all excellence than anything else in the whole of nature. Yet without sharing in the en-

opposite point, this line must pass through the centre of the system. And, in fact, it comes very exactly to Sirius, the brightest star in the whole sky, which, on account of this happy concurrence harmonizing so well with its preponderating form, seems to deserve its being held to be the central body. According to this idea, it should also be seen just in the zone of the Milky Way, if the position of our sun, which diverges somewhat from the plane at the tail of the Eagle, did not cause the optical distance of the centre to be displaced towards the other side of the zone.

thusiastic notion of the Englishman regarding the various stages of the spiritual word, as arranged according to the physical relation of their dwelling-places to the centre of the creation, I am inclined to seek the most perfect classes of rational beings with more probability far away from this centre rather than close to it. The perfection of creatures endowed with reason, in so far as it depends on the quality of the matter in whose bonds they are confined, turns very much on the fineness of the matter which influences and determines them to their perception of the world and their reaction upon it. The inertia and resistance of matter limits very much the freedom of the spiritual being for action and the distinctness of its sense of external things; this makes its faculties dull and obtuse, so that it does not respond to their outward movements with sufficient facility. Hence, if it is supposed, as is probable, that the densest and heaviest sorts of matter are near the centre of nature, and, on the contrary, that the increasing degrees in its fineness and lightness—according to the analogy which rules in our system—are respectively at a greater distance; the result in consequence is intelligible. The rational beings, whose place of generation and abode is found nearer the centre of the creation, are plunged in a rigid and immobile kind of matter which holds their powers shut up in insuperable inertness, and which of itself is just as incapable of transferring and communicating the impressions of the universe with the necessary distinctness and facility. These thinking beings will therefore have to be reckoned as belonging to the lower class. And, on the other hand, with the various distances from the universal centre, this perfection of the world of spirits, which rests on their altered dependence on matter, will grow up like an extended ladder. In consequence of this ardour, the worst and most imperfect species of thinking natures will have to be placed in the deepest point of the descent to the lowest level, and so on downwards, until we reach a point at which this excellence of the rational beings, after passing through all shades of diminution, is lost at last in a total want of reflection and thought. In fact, when it is considered that the centre of nature is at the same time the beginning of its formation out of the raw material, and forms its boundary with chaos; and when it is added that the perfection of spiritual beings has the extreme limit of its beginning where their capabilities are in contact with the irrational, and that there is no limit to the progress beyond which they could not be carried, but that on this side there is a complete infinitude before them; and if there is indeed a law according to which the dwelling-places of the rational creatures are distributed according to the order of their relation to the common centre,—then the lowest and most imperfect species which constitutes, as it were, the beginning of the race of the world of spirits, will have to be located at that place which may be called the initial point of the whole universe. And it must be so located in order that, along with the movement of the universe in its equable progression, that life may also go on which has to fill all the infinitude of time and space with stages of perfection in thought that grow on to infinity, and which has to approach, as it were, step by step, the goal of the supreme excellence of the Deity, without, however, being ever able to reach it.

APPENDIX A.

DIETERICH'S SUMMARY OF KANT'S THEORY OF THE HEAVENS.[1]

NINE years after the appearance of his treatise on the *True Estimation of Living Forces*, Kant published his first important work under the title, *Universal Natural History and Theory of the Heavens, or an Essay on the Constitution and the Mechanical Origin of the Whole Universe, treated according to Newton's Principles*. The mechanical cosmogony which, at the close of his study at the University, had formed the scientific dream of his youth, he was able, at the beginning of his academic career, to communicate to the world as a complete theory, in this publication. The *Natural History of the Heavens* was the ripe fruit of the thorough study of physical science, and of the energetic philosophical reflection which had occupied Kant, while engaged as a family tutor, for nearly ten years; and it is worthy of being placed by the side of the most important products of his scientific work in his later period. Here the critical philosopher presents himself to us in the fresh, full vigour of the productive power of his manhood, "with the courage of the intellectual discoverer and conqueror"; and we have before us the result of his first striving after intellectual achievement, the product of his youthful formative power, which had been only announced in the treatise on the mechanical controversy about the measuring of forces. W. von Humbold cannot but carry our approval when he

[1] *Kant und Newton*, von Dr. Konrad Dieterich, Abschnitt II., pp. 16-33, Tübingen, 1876.

declares that Kant's peculiar genius shines forth most radiantly in his views on the Structure of the Starry Heavens; for the subject-matter, which is of itself of a sublime nature, here furnishes the imagination with a wide field under the leading of a great idea. How deeply the thought of his Cosmogony filled Kant's soul is evidenced by himself, even in his later years, when, at the close of his *Critique of Practical Reason*, he breaks forth in the striking words: "Two things there are that fill the soul with ever new and increasing wonder and awe, the oftener and the more persistently our reflection is occupied with them—the Starry Heavens above me and the Moral Law within me." The ideas of Newton's *Natural Philosophy*, which drew Kant's thought into their magic circle with such irresistible and lasting attraction, and which was the ruling centre of his own striving from the very beginning of his scientific development, are now seen to be carried out with equal independence and logical sequence, on the basis of incessant labour of thought. The magnificent idea of a strictly regulated and ascending evolution of the universe, the idea of a mechanical connection in nature embracing the whole history of the System of the Planets and Fixed Stars, had hovered as a beautiful ideal in a yet uncertain way before the eyes of the youth of twenty-two; and now it gained a definite form in the mind of the man of thirty-one, and is unveiled by him in its sharp outlines before our gaze.

Newton had stopped short at the origin of our Planetary System. But Kant dares to represent the *Natural History of the Heavens* as a necessary consequence of Newton's theory, or as a logical development of it. The spirit of the author of the *Principles of Natural Philosophy* imperatively demanded that the natural causal exploration in the domain of astronomy, should be extended as far as possible. To the scholar it seemed a vital question for the exact science which had been carried by his master to a perfection hitherto unattained, that all supernatural interferences should be banished from the connection of the development of nature; and that its most complicated forms should be derived from the universal Laws of Motion regulating the simplest elements of matter. The recognition of the boundary line which Newton had drawn between

Nature and the Finger of God, seemed to him a sorry conclusion for a philosopher.

Nevertheless the impulse of self-conservation in the sphere of exact Physical Science, was to Kant a powerful impulse, impelling him to advance boldly upon the path trodden by Newton. And not merely so, but the sober realized facts of experience seemed to speak against the acceptance of sudden miraculous acts of creation, and to favour the hypothesis of a constant evolution proceeding according to mechanical laws. The motions of our Planetary System show a striking simplicity and uniformity; and, reasoning from the analogy of mechanical experiments that can be continually repeated, it is very probable that simple and constant moving forces of matter were operative in originating them. But along with great regularity, manifold deviations and unconformities likewise appear. Such defects are only conceivable as disturbances within a natural process which proceeds according to mechanical laws, as collateral effects of the universal natural forces which are not directed merely to the production of particular products, as consequences of the plurality of circumstances which co-operate in the case of every natural occurrence.

A mechanical cosmogony, being thus not in conflict with the thorough observation of facts, has no occasion to fear coming into collision with the requirements of religious feeling—to spare and respect which lay not less strongly at the heart of the pious mind of Newton than did the satisfaction of the needs of the understanding. A deeper religious speculation is not really out of harmony with the theory of a gradual natural creation, which seemed to endanger the ideal interests of the soul; on the contrary, it finds in that view a far surer support than the common theological view of nature—living as it does on a constant footing of war with experience—is capable of furnishing it. For the purposiveness which realizes itself by the simplest means of mechanics, and which nature actually exhibits throughout her whole domain as the result of her gradual development, together with the various undesigned collateral consequences, points to a rational single ground and principle of the whole mechanism of nature. Because the regulated reciprocal play of the atoms brings about an harmonious constitution of the universe, the atoms must be ruled by an inner tendency to the most perfect organization possible; and this finds its most satisfying explanation in their common origin from the Being of the Deity. Moreover, because the mechanical evolution of nature produces rational products, it must be internally animated by a plan of creation, thought out on the great scale. And this thought of a Divine Reason indwelling in the logical mechanism of the simple material forces, leads to a sublimer idea of the Deity, to a more worthy representation of nature as the work of its Creator's power, and to a more living inward perception of the relationship between God and nature than the view that nature is, as it were, an adverse subject which must first be forced by external compulsion into obedience to the commands of reason.

Taken in the way of the causal explanation of nature, as well as of the religious contemplation of the world advocated by Newton, and supported on the weighty foundations of experience, the hypothesis of a mechanical origin of the System of the Planets and Fixed Stars may cherish the hope of a favourable issue and reception. It is constructed very happily in detail. All that is gratuitously presupposed is only this, that the matter out of which the present heavenly bodies consist was at one time decomposed into its elements and dispersed through infinite space, and that the material elements existing in such a state of dispersion showed certain differences in respect of their gravity. It is in some measure an undecided question as to whether this chaos of the minutest particles of matter should be represented as at rest or in motion, in that supposed initial state. In his *Natural History of the Heavens* Kant speaks occasionally of an initial state of rest, in attachment to the thoughts expressed in his first publication. Afterwards in 1785 he assumes a first motion of the atoms in space, but renounces the attempt to give it any further derivation.

To the elements of matter there are to be ascribed, as original forces, the Forces of Attraction and Repulsion, which have been universally recognized since Newton and certainly established. By the operation of these simple fundamental forces motion comes into the chaos, and the further course of this motion is determined until it ultimately brings about the present state of the System of the World. The heavier elements begin to attract the lighter. There thus arises a universal movement towards *one* gravitating point. But in the course of this movement the material particles that are gravitating simultaneously in a straight line towards the centre of the whole system mutually repel each other, and in this manner experience a deviation of their path from their direction in a straight line to the centre. The consequence is a universal whirling movement of the elements, with the most manifold mutual disturbances and frictions, which lead ultimately to a universal circular movement limited, as far as possible, to one plane—as the state of the slightest hindrance, or of the least reciprocal action. Within the disc of atoms moving circularly around the centre of the whole, there arise single centres of smaller masses, around which the matter in their environment gradually groups itself according to the laws of attraction. In this way, by condensation of that disc-like mass of vapour into smaller connected systems of elements, the individual heavenly bodies are agglomerated and form globes. They move in the same form—in a circular path; in the same direction—in the direction of the rotation of the sun around its axis; and in the same plane—in the prolonged plane of the sun's equator—as do the material elements out of which they have been composed.

The deviations from the regular circular form and the common plane, are explained from small differences between the velocity of the original elements, and from the merely approximate limitation of their earlier circular movement to *one* plane. The inclination of the axes of the several heavenly bodies to the plane of their path is presumably to be referred to transformations of their surfaces, which were fluid at the beginning. For with the condensation of the primordial vaporous matter diffused through space, there comes in at the same time an enormous development of heat—a view that is more exactly carried out in Kant's treatise of 1785 on the *Volcanoes in the Moon*, which draws attention to chemical attraction along with mechanical attraction.

In the way thus stated Kant supposes that our Solar

System, probably also the similarly organized System of the Fixed Stars, and perhaps the whole Universe, have been formed. For our Planetary System at least, there follow, unsought, certain consequences from the mechanical theory of its origin, which agree in a striking manner with facts of observation that lay originally quite away from it. These are supplementary confirmations of the hypothesis by experience, which are fitted to lend it that certainty which any hypothesis as such is capable of receiving. One of these facts is the relation between the density of the sun and the average density of the planets, which the calculation of Buffon had established. The other fact is the form and time of the revolution of Saturn's Ring, which Kant first deduced from its supposed mechanical origin, and which was brilliantly established a considerable time afterwards by Herschel's observation.

The strictly scientific view of the evolution of the Solar System—which may be extended to every other cosmic system of similar constitution—was expanded in the mind of Kant into a poetical representation of the evolution of the whole Universe, but which he sharply distinguishes as imaginative speculation from his astronomical theory. The mechanical cosmogony opens up an enormous perspective into immeasurable distances of time and space; it lets us look back into the remotest past of our Planetary System and look out to unlimited connections of this system with ever more widely extended higher systems. The imagination cannot deny itself the charm of sweeping, under the guiding thread of analogy, beyond the bounds still accessible to scientific calculation and shaping out for itself a single collective view of the eternal economy of the whole universe. Natural science draws with certainty only the lines within which the Solar System, and perhaps also the System of the Fixed Stars, has developed itself from its simplest beginnings down to the present time; it gives us no definite information about the earlier history which preceded that state of vaporous dispersion, nor about the later history which will follow the development hitherto. If we allow ourselves to step into the domain of mere conjecture, it is very probable that the same mechanical laws which led to the formation of a system of celestial bodies, will likewise draw after them its destruction of necessity. But, on the other hand, it is also probable that there will lie a seed of renovation in the crash and chaos of shattered worlds.

According to the analogy of all other forms of production in external nature, which consist of a continual change between the combination and separation of constant elements, every cosmic system—as well as every smaller formation which the universal mechanism produces—will complete its course at some one point of time, just as it began it in time. When a world has developed its original capacities and exhausted its inner store of energy, it can then only play the last part in the drama of its changes—namely, pay its debt to mortality. But because every world hastens to its destruction with a tendency, founded indubitably in mechanical laws, and therefore already designated by Newton as thoroughly natural and inevitable, it is to be expected that nature in her boundless fruitfulness, which is everywhere observable, will make up for any ending in one place of the universe by a compensation at another, and will continually maintain herself scatheless by innumerable new productions through the whole extent of her economy. We observe, moreover, that nature goes with extraordinary prodigality to work in her productions, and that she continually disseminates a superfluity of seeds and germs. This, her way of counting with large numbers and carrying on her housekeeping in the grand style, will surely also find expression in the development of the whole universe. As she destroys without scruple small creatures, and higher or lower ones in the same manner, because their production costs her nothing, so she regards a world or a Milky Way of worlds not otherwise than a flower or an insect, because the infinitude of the creation is great enough to let even them disappear again from the scene. The transitoriness of the greatest world-systems, which are all swallowed up by the abyss of the eternities, thus furnishes us with a weighty reason for supposing that the whole creation extends to infinity in time and space, as soon as we have recourse to the analogy of the usual procedure of nature that is accessible to our immediate experience.

Thus then there presses itself immediately upon our fancy a conception of the History of the Universe to this effect: that the organization of the raw material out of which it is built has begun at some one point of space and in some one moment of time; and that it has thence progressed as an advancing formation of unlimitedly many worlds in *one* determinate direction, namely, from the centre away into infinite space. Backwards from the momentary culmination of the process that progresses to infinity in the form of a constantly expanding circle, old worlds fall away; and forwards, new worlds are formed. A complete cessation will never come in. A developed world will always be found existing between the ruins of the nature that has been destroyed and the chaos of the nature that is still unformed. To-day we look out on the one side to an infinite host of ordered worlds which march slowly but surely to their dissolution, although thousands, perhaps millions, of centuries may have to pass before that dissolution finally comes. On the other side, there lies before us the infinite storehouse of chaos, buried in silent night, yet full of materials and springs of motion for the animation of the still desert regions of space beyond.

But this representation is not able yet to satisfy our imagination completely, which would extend its view from the eternal process of creation even away beyond that first assumed point of beginning in time. Whence has sprung the chaotically dispersed material of the self-organizing systems; and what will become of the fragments of the disorganized systems? Is it not possible to imagine the process of the world as an infinite circulation rather than as a motion advancing in an unlimited straight line? If we connect the initial and final points between which the evolution of a single world-system runs its course, perhaps the ring will be closed. A new point of view thus presents itself to us from which we are able to contemplate the history of the universe, even although it should be limited in space, as an eternal process—an endless becoming.

We obtain the grandest idea of the economy of the whole of nature, when we regard the ruins of perished worlds as the raw material of endless new formations. Nature appears to us as a phoenix which consumes herself only in order to arise out of her own ashes, and to live again in renewed youth. This idea permits us even to conceive of a system equipped with limited means, a universe of a finite extent and with a finite store of energy, which, by the opposition of the constantly changing combination and dissolution of its minutest parts, may be passing through a history unlimited in time, backwards as well as forwards. When therefore the planets, along with the comets, in consequence of the exhaustion of their revolving motion, shall some day plunge into the sun; when the infinite accession of heat which the sun will experience by this collision, dissolves it into its elements, and disperses these elements in all directions: then the materials thus diffused in space after they have again cooled down and been left to the operation of their attracting and repelling forces, will begin anew the former process of world-forming. And if a single planetary system has repeated more than once this play of the process of decay and restoration by its inner mechanical forces, the higher system to which it belongs may well follow its example.

The world of the spiritual life arises upon the basis of nature, in her process of eternal self-rejuvenation, as she describes her endless circle between the poles of the composition and the decomposition of her atoms, on the great as on the small scale. The speculative imagination cannot resist the temptation to draw the evolution of the spirit likewise into the sphere of her universal poetic view of the eternal process of the universe. For Kant there thus already lie in the Natural Philosophy which springs from the bosom of his mechanical cosmogony, the germs of a Philosophy of History. With a few strokes he sketches at least the outlines of a representation of the spiritual world, which completes his philosophical view of nature, by carrying it out to a comprehensive view of the world as a whole. The sketch of this picture undoubtedly bears the impress of the original spirit of Leibnitz, which revived in the historical speculations of Lessing and Schiller; yet in its colouring there are unmistakable Kantian features which reappear especially in Schiller.

We find nature and spirit on our earth in closest connection; and it may be conjectured that this relation between them is repeated through the whole universe.

Corresponding to the process of the physical world, the life of the spirit will therefore also, of course, exhibit an ascending development, embracing all the possible degrees of perfection. But we must not think of the spiritual world as enclosed in the narrow frame of the history of mankind; it doubtless extends over all the habitable heavenly bodies. The mechanical cosmogony destroys in fact the dream that man forms the ultimate goal of the whole development of the world; and it makes us familiar with the thought that the purpose of nature lies in the infinite fulness of the manifold life which it brings forth everywhere. If we limit ourselves to the solar system, in our speculative imaginings regarding the spiritual world, we may suppose that the perfection of the inhabitants of the planets constantly increases from Mercury to Saturn, so that perhaps on Mercury a Greenlander or a Hottentot would be considered a Newton, while on Saturn a Newton would be wondered at as an ape. This thought is suggested by the conjecture that the organization of the planets becomes always finer with their greater distance from the sun, corresponding to the diminution of their density in that direction. For the more perfect the external physical conditions of life are, that are furnished by the material dwelling-place of spiritual beings, in virtue of all its qualities, so much the more tender is the corporeal organization of these beings themselves. But with the greater elasticity of the body, so far as we can observe, the intellectual capabilities of the soul reach a higher development.

The dependence of the spiritual life on the physical circumstances of a planet may serve as a guide for analogical inferences as to the constitution of a spiritual kingdom extended beyond the whole solar system, and it is a manifest fact if we stop on the sure soil of our earth. But here it must also form the starting point of a philosophical view of the history of humanity. *A History of Civilization has to be founded upon a Natural History of Mankind.* Again, a *Natural History of the Earth* joining on to the Universal Natural History of the Heavens, is the presupposition of a Natural History of Mankind. There thus grow out of the *Natural History of the Heavens* two branches of special investigation in the

Philosophy of Nature, which lead from Natural Philosophy to Anthropology and Philosophy of History.

The fundamental psychological views from which he proceeds in working out his further philosophical ideas about the development of the spiritual world, are characteristic of Kant. If the distinctness of our ideas and the sharpness of our conceptions are conditioned by the anatomical and physiological condition of our organism, and especially by the circulation of the blood and the activity of the nerves, then the fundamental law of the evolution of the physical world will also rule the life of the spirit. The lever of all the material processes of the universe is the *opposition of different forces.* The interplay of Newton's pair of forces—attraction and repulsion—fashions heavenly bodies and world-systems out of the chaos of the beginning, and shatters them to pieces again in order to form new products out of their ruins. This struggle of opposite forces is continued in the tumult of the elements which maintain the machine of the human body; and it is also reflected in the storms of the passions which move the life of the soul with deafening and disturbing violence. As all the life of nature rests upon a conflict of her forces, so the life of the spirit proceeds from a *conflict of opposite impulses.*

For Leibnitz there were in the physical as in the psychical domain, only ideal relations of an inner harmony. In the mind of Newton the process of nature was reflected as a real interaction of elements struggling in actual conflict with each other. To the eye of Kant the history of mankind—like the history of nature apprehended in the sense of Newton—did not present the picture of a smooth and even flow of ideas, but what it presents is a conflict of impulses, feelings, and passions, engaged in hard combat with each other. As the general idea of evolution was a thought of Leibnitz, so the idea of a process *moving through oppositions*, of which the keynote was sounded by Heraclitus, is an idea of Newton's philosophy. But this idea found a living and independent echo in Kant's own thinking; and in its definite application to the life of the spirit it is to be regarded as emanating from his peculiar practical mode of thinking. No sooner does Kant's view of nature throw some streaks of light upon his view of human society than already there is announced that energetic, heroic, and severe *practical* characteristic which was to be introduced by him into German speculation. This opposition to Leibnitz also appears in the fact that, in spite of all his psycho-physical mode of viewing the conflict between sensuous and rational impulses, there is ascribed to the spirit the capability of resisting the sensuous impulse, if it only *will*. The moral condition of man depends indeed in a high degree on his intellectual development; but if the spirit does not possess dominion over the sensuous nature, it is all the same the fault of its own inertness. It is likewise characteristic of Kant, that with all the charm which physical speculation at that time decidedly had for him, he yet desired to found the moral ideal of the eternal destination of man upon an immediate inner certainty of feeling, which was held to be completely independent of all metaphysical fancies.

APPENDIX B.

THE HAMBURG ACCOUNT OF THE THEORY OF THOMAS WRIGHT OF DURHAM.[1]

LONDON.

THERE has been published here: "An Original Theory or New Hypothesis of the Universe, Founded upon the Laws of Nature, and solving by Mathematical Principles the General Phenomena of the Visible Creation; and particularly the Via Lactea. Comprised in Nine Familiar Letters from the Author to his Friend. And illustrated with upwards of thirty graven and mezzo-tinted Plates by the best Masters. By Thomas Wright, of Durham. London, MDCCL."[2] It is rightly remarked by this ingenious author that "in a System naturally tending to propagate the principles of virtue and vindicate the laws of Providence, we may indeed say too little, but cannot surely say too much; and to make any apology for a work of such nature, where the glory of the Divine Being of course must be the principal object in view, would be too like rendering virtue accountable to vice for any author to expect to benefit by such excuse." In another passage he says, "In a word, when we look upon the universe as a vast infinity of worlds acted upon by an eternal Agent, and crowded full of beings, all tending through their

[1] Translated from the MS. Excerpt Copy, in the Edinburgh University Library, from the FREYE URTHEILE UND NACHRICHTEN ZUM AUFNEHMEN DER WISSENSCHAFTEN UND DER HISTORIE ÜBERHAUPT. Achtes Jahr, I. Stück. Hamburg, bey Georg Christian Grund, den 1 Januar, 1751.

[2] The title and following quotations are all given here as they run *verbatim* in the original English text of Wright's work.

various states to a final perfection, and reflect upon the many illustrious personages who have from time to time thought it a kind of duty to become observers and consequently admirers of this stupendious sphere of primary bodies, and diligent enquirers into the general laws and principles of nature; who can avoid being filled with a kind of enthusiastic ambition, to be acknowledged one of the number, who, as it were, by thus adding his atom to the whole, humbly endeavours to contribute towards the due adoration of its great and Divine Author." This work rightly deserves the attention of every reader; and hence our notice of it will be the more circumstantial. But as the author has illustrated his work with various beautiful copper-plates to which we cannot refer in this excerpt, we shall have to pass over many passages. The following will however suffice to give our readers a favourable idea of the work.

THE FIRST LETTER is entitled: "*Concerning the opinions of the most eminent authors whose sentiments upon this subject have been published in their works.*" In this letter Mr. Wright first endeavours to commend diligent application to the knowledge of nature by adducing the important advantages which flow from it, and then he proceeds to quote the opinions of the most famous writers concerning his first proposition, namely, that the stars are all suns and are surrounded with planetary bodies. The writers quoted are Jordanus Bruno, Milton, Christian Hugenius, Christopher Huygens, Isaac Newton, Dr. Derham, Mr. Harvey,[1] Dr. Young, Mr. Pope, and so on.

THE SECOND LETTER is entitled: "*Concerning the nature of mathematical certainty and the various degrees of moral probability proper for conjecture.*" In this letter the author shows that in things where no mathematical demonstration can be expected we must be satisfied with moral certainty; and where a demonstration is wanting we must employ another method for judging by, in order to convince any one of the point in dispute, namely, "by the analogy of known and natural things." In order to explain what he means by moral certainty and by mathematical proof he gives examples of both. He observes

[1] *Contemplations on the Starry Heavens.*

at the same time, that many of the modern discoveries [of Sir Isaac Newton], "such as relate particularly to the Planetary System, are but as so many confirmations of the conjectures and imaginations" of the ancients, who, as they were not able to demonstrate these things mathematically, employed merely an analogical way of judging, and they left the establishment of their views to posterity. That the reader may be able to form an idea of the astronomy of the ancients, he shows how far they carried their speculations concerning the visible creation, and with this he concludes the second letter.

THE THIRD LETTER treats: "*Concerning the nature, magnitude, and motion of the planetary bodies round the Sun, etc.*" In this letter Mr. Wright gives a brief sketch of the astronomy of Copernicus, and explains the magnitudes, distances, motions, and revolutions of the planets and comets. Concerning the latter he appears to have made a very happy remark, for, in so far as it should be found true, it would contribute very much to complete the theory of the comets. He says, "I am strongly of opinion that the comets in general, through all their respective orbits, describe one common area, that is to say, all their orbits, with regard to the magnitude of their proper planes, are mathematically equal to one another; which, if it once could be proved, and confirmed by observation, the theories of all the comets that have been justly observed, might easily be perfected, and their periods at once determined, which now we can only guess at, or may wait whole ages for more certainty of. What leads me to believe that this may prove to be really the case is this. I find by calculation that the orbits of the two last comets, whose elements have been most corrected by Sir Isaac Newton and Dr. Halley, are to one another according to their numbers nearly as 13 : 17, notwithstanding one of them is one of the most erratic that ever came under our observation; and the other one of the most neighbouring to the sun. But it is well known to all mathematicians that the first of these comets moved in so eccentric a trajectory, that the least error in its almost incredible proximity to the sun will produce a very sensible difference in the area of the orbit. And accordingly, if we moderate the Perihelion distance of this comet by making it but 1000 instead of 612, which is but increasing a $\frac{1}{35000}$th part of the great radius of the orbit (which is an error every astronomer will readily grant is very easily made), and we shall find the orbits of the said two comets to be exactly equal. Further, I must inform you that the comet of 1682, which the above [is] compared with, seems to have been so accurately observed that it does not appear to have altered its Perihelion distance half $\frac{1}{68}$th part in one entire revolution. Now, if we can with any show of reason, and a probability on our side, bring the areas of these two extreme comets, as I may call them, to an equality, sure we may conclude it is a subject highly worthy to be more considered and enquired into." Thereupon he proceeds to prove that all the light of the planets and of their satellites or moons is borrowed from the sun, they being, in fact, dark bodies. "Now," he says, "to convince you that the planets are all in their own nature no other than dark opaque bodies reflecting only the borrowed light of the sun, I must recommend to your observation this natural and simple experiment, which almost any opportunity of seeing the moon a little before the full, will put into your power to make; but best and easiest when the sun is in any of the North Signs, *i.e.* in *summer*. At such a time the sun, being near setting, the moon will appear in the eastern hemisphere; and if there be any bright clouds northward or southward near her, you will plainly perceive that the light of the one is of the same nature with that of the other; I mean the light of the moon and that of the cloud. To me there never appeared any difference at all; and I am persuaded were you to make but two or three observations of this kind, which is from nature itself, a sort of ocular demonstration, you cannot fail of being convinced that the moon's light, such as it is, without heat, can possibly proceed from no other cause than that which illumines the cloud. For, if the clouds whose composition we know to be but a thin light fluid, formed of condensed vapours only, is capable of remitting so great a lustre, how much more may we not allow the moon, which length of time and many other circumstances have long confirmed, to be a durable and solid body."

THE FOURTH LETTER is entitled: "*Of the nature of the Heavenly Bodies continued, with the Opinions of the*

Ancients concerning the Sun and Stars." Mr. Wright here shows that the stars are not only "light bodies" like the sun, but are also actually so many suns which all show the same effects of heat and gravity in regular order through the whole visible creation. He first remarks that the burning-glass has shown, beyond all question, "that the sun is a vast body of blazing matter"; and thereafter he endeavours to prove that the stars are of a similar nature by the following considerations: First, every visible thing of any determinate magnitude may be reduced to the appearance of a physical point, if the eye of the person who looks to it is brought in the finite sphere of vision to a proper distance from it; and certainly "they are no other than vast globes of blazing matter, all undoubtedly shining by their own native light." But in order that it may not be objected that the distance of the stars may be generally less than is believed, and that they might therefore have their light from the sun or other radiating body, Mr. Wright proves that this objection is altogether groundless, and to reach this position he first of all removes the following great deception of vision. "Most people," he says, "are too apt to think originally that, as the heavens appear to be a vast concave hemisphere, that the stars must of course, as of consequence, be fixed there, like so many radiant studs of fire of various magnitudes; and take it for granted, chiefly designed for no other purpose than to deck and adorn the canopy of our night." This idea, says the author, was adopted by many of the ancients, whose opinions he quotes; and thereafter he proves that, as these bodies have no sensible parallax, their distance is too great to be capable of being determined by the greatest perfection of human art. He then proceeds to show that the light of the fixed stars is native to them. "All objects," he says, "within the sensible sphere of the sun's attraction or activity, are in some measure magnified by a good telescope. But the stars are all placed so far without it that the best glasses has (*sic*) no other effect upon them than making them appear more vivid or lively; but all innate opaque bodies, reflecting only a borrowed light from some primary one, contrary to this property, are all observed to lose their light in the same proportion as

THOMAS WRIGHT OF DURHAM, MATH. ET NAT. PHIL. PROF.

MDCCXI—MDCCLXXXVI.

they are magnified, and through all glasses become more dull than otherwise they appear to the naked eye. And hence we may infer, without any further evidence, that the stars are all light bodies endowed with native lustre; and that bodies like the known planets, from the same reasoning, it is as clear they cannot be, because their distance would render them all in such a case invisible. A proof of this will plainly present itself if we consider the course of the known comets, who all of them, without exception, become imperceptible and entirely disappear; though most of them much bigger than the earth or any of the lesser planets long before they arrive at their respective Aphelions. But we are under a kind of necessity to believe them either suns or planets, that is, either dark or light bodies; and since I have shown the improbability, nay, I may venture to say, the impossibility of their being the first, it is natural sure to conclude that they must be of the last sort." But to put the matter beyond all controversy the author presents the following optical experiment: "Place any concave lens before your eye, and you will find all visible objects will appear through it as removed to a much greater distance than they really are at, and reciprocally as much diminished. Now if you look upon one of these glasses of a proper concavity, opposed to the sun or moon, you will respectively have the appearance of a real star or planet, the first exhibited by the body of the sun, the other by the moon, and either more or less diminished in proportion to the surface of the sphere the glass is ground to. For example, a double concave, or glass of a negative focus, ground to a sphere of about three inches diameter, will, if opposed to the sun's disc at a proper distance from the eye, help you to a very good idea how the sun appears to the planet Jupiter; and if a proper regard be had to the distance of the planet Saturn, a lens still more concave may be formed to give a just idea of the sun's appearance to Saturn. Again, one much more [less] concave than the former, proportioned to the orbit of Mars, will naturally exhibit the solar body as seen from that planet." The author next proceeds "to enquire what the real use and design of so many radiant bodies are, or may be made for. The sun," he says, "we have just reduced to the state of a star, why then in reason should he have his attendant planets round him more than any of the rest, his undoubted equals? No shadow even of a reason can be given for such an absurdity. May we not, with the greatest confidence, imagine that nature as justly abhors a vacuum in place, as much as virtue does in time? Surely, yes! And by supposing the infinity of stars, all centres to as many systems of innumerable worlds, all alike unknown to us, how naturally do we open to ourselves a vast field of probation and an endless scene of hope to ground our expectation of an ever future happiness upon, suitable to the native dignity of the awful Mind which made and comprehends it, and whose works are all as the business of an eternity! If the stars were ordained merely for the use of us, why so much extravagance and ostentation in their number, nature, and make? For a much less quantity and smaller bodies placed nearer to us would everyway answer the vain end we put them to; and besides, in all things else nature is most frugal and takes the nearest way through all her works, to operate and effect the will of God. It scarce can be reckoned more irrational to suppose animals with eyes destined to live in eternal darkness, or without eyes to live in perpetual day, than to imagine space illuminated where there is nothing to be acted upon or brought to light; therefore we may justly suppose that so many radiant bodies were not created barely to enlighten an infinite void, but to make their much more numerous attendants visible; and instead of discovering a vast, unbounded, desolate negation of beings, display an infinite shapeless universe, crowded with myriads of glorious worlds, all variously revolving round them; and which, from an atom to an indefinite creation with an inconceivable variety of beings and states, animate and fill the endless orb of immensity." After having remarked that there can be no objection raised against the actual existence of the planets of the Fixed Stars, because their revolution around these stars is invisible, and further because the stars themselves appear to us upon the earth almost as mathematical points, it must therefore be impossible to discover their dark attendants, he adds: "Let us suppose a new created mind, or thinking being, in a profound state of ignorance with regard to the nature of all external objects, but fully endowed with every human sense and force of reason, suspended in ether, exactly in the midway betwixt Sirius and the Sun, in which case both of these luminaries would equally appear much about the brightness of the largest of our planets. Now, should such a being, determined either by accident or choice, arrive at this our system of the sun, and seeing all the planetary bodies moving round him, I would ask you what you think he would imagine to be round Sirius? Your answer, I think I may venture to say, would not be, *nothing*; and methinks I already hear you say, *Why, Planets such as ours.*" The rest of this letter is filled with purely moral reflections.[1]

THE FIFTH LETTER treats: "*Of the order, distance, and multiplicity of the stars, the Via Lactea, and extent of the visible creation.*" Before the author comes to the solution of the phenomena of the Milky Way, he presents the ideas of the ancients regarding it. He holds that "The light which naturally flows from this crowd of radiant bodies is mixed and confused, chiefly occasioned by the agitation of our atmosphere; and from a union of their rays of light, by a too near proximity of their beams, altogether they appear like a river of milk, but more of a pellucid nature, running all round the starry regions." In confirmation of this, he shows that the various cloudy stars [Nebulae] or light appearances in the heavens can be nothing but a dense accumulation of small stars. He then proceeds to say: "Now, admitting the breadth of the Via Lactea to be at a mean but nine degrees, and supposing only twelve hundred stars in every square degree, there will be nearly in the whole orbicular area 3,888,000 stars, and all these in a very minute portion of the great expanse of heaven. What a vast idea of endless beings must this produce and generate in our minds; and when we consider them all as flaming suns, progenitors, and *primum mobiles* of a still much greater number of peopled worlds, what less than Infinity can circumscribe them, less than an Eternity comprehend them, or less than Omnipotence produce and support them, and where can our

[1] The remaining part of this account appeared in the next issue of the Hamburg periodical of Friday, 8th January, 1751, headed: "London, Conclusion of the Account," etc.

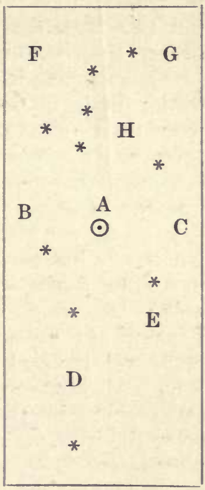
wonder cease?" He further says: "Perhaps you may expect that I should here give you my conjectures of what sort of beings may be supposed to reside in the *Ens primum*, or *Sedes beatorum*, of the known universe, . . . but this is a task above the human capacity, or is the pure province of religion alone; the business of a revelation rather than reason to discover.

THE SIXTH LETTER is entitled: "*Of general motion amongst the stars, the plurality of systems, and innumerability of worlds.*" In this letter the author endeavours to prove that all the stars are in motion, and he ascribes the alteration in the obliquity of the ecliptic to the motion of the sun round the centre of the universe.

THE SEVENTH LETTER is entitled: "*The Hypotheses or Theory fully explained and demonstrated, proving the Siderial Creation to be finite.*" After a digression on the utility of astronomy, the author endeavours to solve the phenomena of the Milky Way in the following manner: "Let us imagine a vast infinite gulf or medium, every way extended like a plane, and enclosed between two surfaces, nearly even on both sides, but of such depth or thickness as to occupy a space equal to the double radius or diameter of the visible creation, that is, to take in one of the smallest stars each way from the middle station, perpendicular to the plane's direction, and as near as possible according to our idea of their true distance. But to bring this image a little lower and as near as possible level to every capacity (I mean such as cannot conceive this kind of continued zodiac), let us suppose the whole frame of nature in the form of an artificial horizon of a globe. I don't mean to affirm that it really is so in fact, but only state the question thus to help your imagination to conceive more aptly what I would explain. Plate XXIII. will then represent a just section of it.[1] Now in this space let us imagine all the stars scattered promiscuously, but at such an adjusted distance from one another as to fill up the whole medium with

[1] The relative positions of the letters in this diagram referred to may be indicated. The whole space or medium contained within the section BFGCD is represented as filled with large and small stars, and lines are drawn towards and through them in the visual directions, from A to B, F, H, G, and E respectively.—Tr.

a kind of regular irregularity of objects. And next, let us consider what the consequence would be to an eye situated near the centre point or anywhere about the middle plane, as at the point A. Is it not, think you, very evident that the stars would there appear promiscuously dispersed on each side and more and more inclining to disorder as the observer would advance his station towards either surface and nearer to B or C; but in the direction of the general plane towards H or D by the continual approximation of the visual rays crowding together, as at H betwixt the limits D and G, they must infallibly terminate in the utmost confusion. If your optics fail you before you arrive at these external regions, only imagine how infinitely greater the number of stars would be in those remote parts, arising thus from their continual crowding behind one another, as all other objects do towards the horizon point of their perspective, which ends but with infinity. Thus all their rays at last so near uniting must, meeting in the eye, appear as almost in contact, and form a perfect zone of light. This I take to be the real case and the true nature of our *Milky Way*; and all the irregularity we observe in it at the earth, I judge to be entirely owing to our sun's position in this great firmament, and may easily be solved by his excentricity and the diversity of motion that may naturally be conceived amongst the stars themselves, which may here and there, in different parts of the heavens, occasion a cloudy knot of stars, as perhaps at E.



"But now to apply this hypothesis to our present purpose and reconcile it to our ideas of a circular creation and the known laws of orbicular motion, so as to make the beauty and harmony of the whole consistent with the visible order of its parts, our reason must now have recourse to the analogy of things. It being once agreed that the stars are in motion, which, as I have endeavoured in my last letter to show, is not far from an undeniable truth, we must next consider in what manner they move. First then, to suppose them to move in right lines, you know is contrary to all the laws and principles we at present know of; and since there are but two ways that they can possibly move in any natural order, that is, either in right lines or in curves, this [not] being one it must, of course, be the other, *i.e.* in an orbit; and, consequently, were we able to view them from their middle position . . . we might expect to find them separately moving in all manner of directions round a general centre. It only now remains to show how a number of stars, so disposed in a circular manner round any given centre, may solve the phenomena before us. There are but two ways possible to be proposed by which it can be done, and one of which I think is highly probable; but which of the two will meet your approbation I shall not venture to determine. The first is in the manner I have above described, *i.e.* all moving the same way, and not much deviating from the same plane, as the planets in their heliocentric motion do round the solar body. . . . The second method of solving this phenomena is by a spherical order of the stars, all moving with different direction round one common centre, as the planets and comets together do round the sun, but in a kind of shell or concave order. The former is easily conceived from what has been already said, and the latter is as easy to be understood if you have any idea of the segment of a globe."

THE EIGHTH LETTER is entitled: "*Of Time and Space, with regard to the known objects of immensity and duration.*"

THE NINTH LETTER contains: "*Reflections by way of general scholia, of consequences relating to the immortality of the soul, and concerning Infinity and Eternity.*" Here we shall only reproduce what the author founds all his reflections in these letters upon. "Should it be granted," he says, "that the creation may be circular or orbicular, I would next suppose in the general centre of the whole an intelligent principle, from whence proceeds that mystic and paternal power productive of all life, light, and the infinity of things. Here the to all extending eye of Providence, within the sphere of its activity, and as omnipresently residing seated in the centre of Infinity, I would imagine views all the objects of His power at once, and everything immediately direct, dispensing instantaneously its enlivening influence to the remotest regions everywhere all around. Having, I say, once granted that all the stars may move round one common centre, I think it is very natural to one, who loves to pursue nature as far as we may, to inquire what most likely may be in that centre; for since we must allow it to be far superior to any other point of situation in the known universe, it is highly probable there may be some one body of siderial or earthy substance seated there, where the Divine Presence or some corporeal agent full of all virtues and perfections more immediately presides over His own creation. And here this primary agent of the omnipotent and eternal Being may sit enthroned, as in the Primum Mobile of nature, acting in consort with the Eternal Will. To this common centre of gravitation, which may be supposed to attract all virtues and repel all vice, all beings as to perfection may tend; and from hence all bodies first derive their spring of action and are directed in their common motions.

"Thus in the focus or centre of creation, I would willingly introduce a primitive fountain perpetually overflowing with Divine grace from whence all the laws of nature have their origin; and this I think would reduce the whole universe into regular order and just harmony, and at the same time enlarge our ideas of the Divine indulgence, open our prospect into nature's fair vineyard, the vast field of all our future inheritance. But what this central body really is I shall not here presume to say; yet I can't help observing it must of necessity, if the creation is real and not merely ideal, be either a globe of fire superior to the sun, or otherwise a vast terraqueous or terrestrial sphere, surrounded with an ether like our earth but more refined, transparent, and serene. Which of these is most probable I shall leave undetermined, and must acknowledge at the same time my notions here are so imperfect I hardly dare conjecture."

APPENDIX C.

PROFESSOR DE MORGAN'S ACCOUNT OF THE SPECULATIONS OF THOMAS WRIGHT OF DURHAM.[1]

M. ARAGO, in his account of William Herschel, published in the Paris *Annuaire* for 1842, recalled the attention of astronomers to the fact that some speculative researches into the constitution of the stellar universe had preceded those of his illustrious subject. He instances Wright, Kant, and Lambert, from the second of whom he draws all his information as to the first. Professor Struve, in his recently published *Etudes d'Astronomie Stellaire*, St. Petersburg, 1847, 8vo, again mentions Wright from Kant, and gives the titles of his works from Lalande. But neither Kant, Arago, nor Struve, had seen the work of Wright in question. I propose to give an account of it, as of a speculation which must take a high rank among those daring and yet sober attempts at prediction of future results, which are, and ought to be, repaid upon success for the contempt with which they are always received on appearance. The author did not, as speculators sometimes do, attempt to discount his fame, and to procure an endorsement of good names for a bill of long date upon posterity. He published his work in a quiet way, and left time to show what it was worth.

The work[2] in question is entitled *Theory of the Universe*,

[1] Reprinted from *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, Vol. XXXII. January-June, 1848.

[2] 'An Original Theory or New Hypothesis of the Universe, Founded upon the Laws of Nature, and solving by Mathematical Principles the General Phænomena of the Visible Creation; and particularly the Via Lactea. Compris'd in Nine Familiar Letters from the Author to his Friend. And Illustrated with upwards of Thirty Graven and Mezzotinto Plates. By the Best Masters. By Thomas Wright, of Durham.

One *Sun by Day, by Night* ten Thousand *shine*,
And light us deep into the DEITY.—DR. YOUNG.

London: Printed for the Author, and sold by H. Chapelle, in *Grosvenor Street*. MDCCL.' Quarto, pp. xii. + 84, plates 32.

and was published in 1750. Kant, as appears by Professor Struve's statement, took his knowledge of it from the *Hamburgische Freie Urtheile* of 1751, and wrote on the same subject in his *Allgemeine Naturgeschichte und Theorie des Himmels*, Leipzig, 1755, 8vo. As far as I can see from Professor Struve's description of Kant's views, there is not in them any extension of Wright's, except in two points, which I shall notice in the proper place.

Wright's work consists of nine letters to a friend, and in its speculations is both astronomical and theological; the latter term including not merely expression of devotional feeling, but much actual conjecture on what astronomy may teach in relation to the future state of mankind. Omitting this, I shall proceed to register the purely astronomical doctrines of the treatise, so far as they seem peculiar to Wright.

I make one long extract from the seventh letter, which might have been shortened, and the English of it made clear and more correct, with no loss to Wright's memory. But as this passage is very important as evidence, and is unquestionably, out of the whole book, that which most nearly contains the pith and marrow of the system, I have thought it best to extract the whole of it.

In the preface it is stated that the chief design is "an Attempt towards solving the Phænomena of the *Via Lactea*, and in consequence of that Solution, the framing of a regular and rational Theory of the known Universe, before unattempted by any." It is ". . . entirely upon a new Plan, and the Beginning, as it were, of a new Science, before unattempted in any Language, the Author having dug all his Ideas from the Mines of Nature . . ." And further, "How the Author has succeeded in this Point, is a Question of no great Consequence; he has certainly done his best; another, no Doubt, will do better, and a third perhaps, by some more rational Hypothesis, may perfect this Theory, and reduce the Whole to infallible Demonstration: . . ."

The claim which Wright makes to originality will easily be admitted; and his priority must remain uncontested until it can be impugned upon evidence. At present, neither Arago nor Struve have met with anything of the same kind anterior to Wright.

In the first letter Wright gives the opinions of preceding authors. He states that his own system was first planned in 1734. I need not describe his very imperfect enumeration of his predecessors. In 1732, *Robert* Wright, whom I ought to mention to prevent his being confounded with the subject of this notice, published his Newtonian lunar tables for the navy.

The second letter is on probability and certainty, and, though ingenious and sound, has nothing to the present purpose. It concludes with an account of celestial systems anterior to that of Copernicus.

The third letter is on the planetary motions and structures. It contains nothing peculiar to Wright, except a declaration that he is strongly of opinion that the orbits of comets have all their areas equal. This is not a happy conjecture. He draws the notion from observing that the comets of 1680 and 1682, the most and least excentric of those whose orbits had been calculated, have areas not very unequal, and such as a supposition of moderate errors of observation might make equal. The following sentence is of a better kind, be the latter part worth what it may. ". . . the Clouds are to us in effect no other than as so many Moons, whereby we have our artificial Day prolonged to us several Hours after the Sun is set, and likewise produced as much sooner before he rises; and were they to ascend by still stronger Power of Exhalation to an Elevation, all round the Atmosphere, so as to form a Sphere equal to four Times the Globe of the Earth, there would then be no such Thing as real nocturnal Darkness to any Part of the World."

The fourth letter continues his remarks on the nature of the heavenly bodies. That the sun is a vast body of blazing matter, he thinks will hardly admit of question: though he afterwards supposes it possible that the igneous matter may be only an envelope. Aberration is spoken of with caution. "Mr. *Bradley*, Astronomer-Royal, has, in a great measure, proved that the Aberration of the Stars hitherto mistaken for a Parallax, may arise from, and indeed seems to be no other than the progressive Motion of Light, and Change of Place to the Eye, arising from the Earth's annual Motion and Direction." His friend is recommended to procure an idea of the appearance of the sun to more distant planets than our own, by means of concave glasses fitted to reduce the apparent diameter duly. The homogeneity of the stars with our sun, both as to constitution and attendant bodies, is strongly insisted on from analogy.

The fifth letter first mentions the milky way, which he says ". . . still continues to be unaccounted for, and even in an Age vain enough to boast Astronomy in its utmost Perfection. What will you say, if I tell you, it is my belief we are so far from the real Summit of the Science, that we scarce yet know the Rudiments of what may be expected from it? This luminous Circle has often engrossed my Thoughts, and of late has taken up all my idle Hours; and I am now in great Hopes I have not only at last found out the real Cause of it, but also by the same Hypothesis, which solves this Appearance, shall be able to demonstrate a much more rational Theory of the Creation than hitherto has been any where advanced, and at the same Time give you an entire new Idea of the Universe, or infinite System of Things." The milky way is then described, and the opinions of the ancients upon it. A plate is given of a portion near the foot of Antinous, as observed by Wright himself with what he calls a very good reflector: the plan was formed "by a Combination of Triangles." He afterwards mentions his observing with a "one Foot reflecting Telescope." Proceeding on the opinion of Democritus and others among the ancients, and on his own partial resolution of the galactic light, he pronounces the phænomenon to arise from a congeries of small stars. He does not seem to be acquainted with the partial resolution made by Galileo: and in general, his reading in astronomy anterior to his own day seems to lie rather in classical or mediæval authors, or their translators and compilers, than in those of the seventeenth century.

Making the assumption that the stars shine by their own light, he proceeds thus: "Here it will not be amiss to observe, that it has been conjectured, and is strongly suspected, that a proper Number of Rays, meeting from different Directions, become Flame; and that hence it may prove not the Sun's real Body which we daily see, but only his inflamed Atmosphere. I begin to be of

Opinion, and I think not without Reason, that the true Magnitude of the Sun is not near what the modern Astronomers have made it; and that it may not possibly be much above two Thirds of what it appears to us; . . . This, tho' I presume to call it at present only mere Hypothesis, will in a great measure account for the excessive Changes in the Constitution of our Air and Atmosphere, which we often find very unnatural to the Season; . . . But all this will very naturally be accounted for by the Levity, or expanding Quality of the Sun's circumambient Flame, or Atmosphere; and hence, according to its various State, being more condensed, or rare, we may have Heat or Cold in the greatest Extream, and alternately so, in a perpetual Vicissitude."

Wright then proceeds to estimate the number of stars in the milky way, and to discuss the question of the distance of stars from our sun. Making the distance of one star from another at least about three thousand times that of the furthest planet from our sun, he argues that ". . . as no sensible Disorder can be observed amongst the solar Planets, what Reason have we to suppose any can be occasioned amongst the Stars, or that a general Motion of these primary Luminaries round a common Center, should be any way irrational, or unnatural?"

The sixth letter is headed 'Of General Motion amongst the Stars, the Plurality of Systems, and Innumerability of Worlds.' That the stars are not promiscuously dispersed, he argues from the phænomenon of the milky way, supposed to be resolvable into stars. He then proceeds to say, "If any regular Order of the Stars then can be demonstrated that will naturally prove this Phænomenon to be no other than a certain Effect arising from the Observer's Situation, I think you must of course grant such a Solution at least rational, if not the Truth; and this is what I propose by my new Theory." Afterwards he adds, ". . . we may reasonably expect, that the *Via Lactea*, which is a manifest Circle among the Stars, conspicuous to every Eye, will prove at last the Whole [creation] to be together a vast and glorious regular Production of Beings, . . . and that all its irregularities are only such as naturally arise from our excentric View: To demonstrate which absolutely and incontestibly, we shall only want this one *Postulata* to be granted, *viz. that all the Stars are, or may be in Motion.*" From thence, presuming the stars to have each its attendant system, and arguing that the motion of each primary itself is no more extraordinary than the motion about its axis (which the sun has), he proceeds to discuss the evidence, as it then existed, for apparent proper motion, and considers such a phænomenon established by various instances, and particularly by Arcturus, from comparison with old observations, after allowance for the varying obliquity of the ecliptic. He then recommends close observation of the distances between each two stars in a cluster, for detection of the proper motions, and ends this letter with an engraving of the Pleiades, laid down from his own observations.

The seventh letter gives the explanation of the phænomenon of the milky way, as now generally received. The following are the first words in which this explanation was ever offered, as it turns out. "But of this I have said enough, and think it is now more than Time to attempt the remaining Part of my Theory.

"When we reflect upon the various Aspects, and perpetual Changes of the Planets, both with regard to their[1] heliocentric and geocentric Motion, we may readily imagine, that nothing but a like excentric Position of the Stars could any way produce such an apparently promiscuous Difference in such otherwise regular Bodies. And that in like manner, as the Planets would, if viewed from the Sun, there may be one Place in the Universe to which their Order and primary Motions must appear most regular and most beautiful. Such a Point, I may presume, is not unnatural to be supposed, although hitherto we have not been able to produce any absolute Proof of it. See *Plate* XXV. This is the great Order of Nature, which I shall now endeavour to prove, and thereby solve the Phænomena of the *Via Lactea*; and in order thereto, I want nothing to be granted but what may easily be allowed, namely, that the *Milky Way* is formed of an infinite Number of small Stars.

[1] Not to mention their several Conjunctions and Apulces to fixed Stars, &c., see the State of the Heavens in 1662, *December* the first, when all the known Planets were in one Sign of the Zodiac, *viz. Sagittarius.*

"Let us imagine a vast infinite Gulph, or Medium, every Way extended like a Plane, and inclosed between two Surfaces, nearly even on both Sides, but of such a Depth or Thickness as to occupy a Space equal to the double Radius, or Diameter of the visible Creation, that is to take in one of the smallest Stars each Way, from the middle Station, perpendicular to the Plane's Direction, and, as near as possible, according to our Idea of their true Distance.

"But to bring this Image a little lower, and as near as possible level to every Capacity, I mean such as cannot conceive this kind of continued Zodiac, let us suppose the whole Frame of Nature in the Form of an artificial Horizon of a Globe, I don't mean to affirm that it really is so in Fact, but only state the Question thus, to help your Imagination to conceive more aptly what I would explain. *Plate* XXIII. will then represent a just Section of it. Now in this Space let us imagine all the Stars scattered promiscuously, but at such an adjusted Distance from one another, as to fill up the whole Medium with a kind of regular Irregularity of Objects. And next let us consider what the Consequence would be to an Eye situated near the Center Point, or any where about the middle Plane, as at the point A. Is it not, think you, very evident, that the Stars would there appear promiscuously dispersed on each Side, and more and more inclining to

		B		F
D		A	H	
	E	C		G

Disorder, as the Observer would advance his Station towards either Surface, and nearer to B or C, but in the Direction of the general Plane towards H or D, by the continual Approximation of the visual Rays, crowding together as at H, betwixt the Limits D and G, they must infallibly terminate in the utmost Confusion? If your Opticks fails you before you arrive at these external Regions, only imagine how infinitely greater the Number of Stars would be in those remote Parts, arising thus from their continual crowding behind one another, as all other objects do towards the Horizon Point of their Perspective, which ends but with Infinity: Thus, all their Rays at last so near uniting, must meeting in the Eye appear, as almost, in Contact, and form a perfect Zone of Light; this I take to be the real Case, and the true Nature of our *Milky Way*, and all the Irregularity we observe in it at the Earth, I judge to be intirely owing to our Sun's Position in this great Firmament, and may easily be solved by his Excentricity, and the Diversity of Motion that may naturally be conceived amongst the stars themselves, which may here and there, in different Parts of the Heavens, occasion a cloudy Knot of Stars, as perhaps at E.

"But now to apply this Hypothesis to our present Purpose, and reconcile it to our Ideas of a circular Creation, and the known Laws of orbicular Motion, so as to make the Beauty and Harmony of the Whole consistent with the visible Order of its Parts, our Reason must now have recourse to the Analogy of Things. It being once agreed, that the Stars are in Motion, which, as I have endeavoured in my last Letter to shew is not far from an undeniable Truth, we must next consider in what Manner they move. First then, to suppose them to move in right Lines, you know is contrary to all the Laws and Principals we at present know of; and since there are but two Ways that they can possibly move in any natural Order, that is either in right Lines, or in Curves, this being one, it must of course be the other, *i.e.* in an Orbit; and consequently, were we able to view them from their middle Position, as from the Eye seated in the Center of *Plate* XXV. we might expect to find them separately moving in all manner of Directions round a general Center, such as is there represented. It only now remains to shew how a Number of Stars, so disposed in a circular Manner round any given Center, may solve the Phænomena before us. There are but two Ways possible to be proposed by which it can be done, and one of which I think is highly probable; but which of the two will meet your Approbation, I shall not venture to determine, only here inclosed I intend to send you both. The first is in the Manner I have above described, *i.e.* all moving the same Way, and not much deviating from the same Plane, as the Planets in their heliocentric Motion do round the solar Body. In this Case the primary, secondary, and tertiary constituent Orbits, &c. framing the Hypotheses, are represented in *Plate* XXII., and the Consequence of such a Theory arising from such a universal Law of Motion in *Plate* XXIII. where B, D denotes the local Motion of the Sun in the true *Orbis Magnus*, and E, C that of the Earth in her proper secondary Orbit, which of course is supposed, as is shown in the Figure to change its sidereal Positions, in the same Manner as the Moon does round the Earth, and consequently will occasion a kind of Procession, or annual Variation in the Place of the Sun, not unlike that of the Equinoxes, or Motion of all the Stars together, from West to East round the Ecliptic Poles, and probably may in some Degree be the Occasion of it. This Angle is represented, but much magnified, by the lines F, C, G, and the Unnaturalness, or Absurdity of a right Line Motion of the Sun by the Line I, H.

"The second Method of solving this Phænomena, is by a spherical Order of the Stars, all moving with different Direction round one common Center, as the Planets and Comets together do round the Sun, but in a kind of Shell, or concave Orb. The former is easily conceived, from what has been already said, and the latter is as easy to be understood, if you have any Idea of the Segment of a Globe, which the adjacent Figures, will, I hope, assist you to. The Doctrine of these Motions will perhaps be made very obvious to you, by inspecting the following Plates. Plate XXIV. Is a Representation of the Convexity, if I may call it so, of the intire Creation, as a universal Coalition of all the Stars consphered round one general Center, and as all governed by one and the same Law. Plate XXV. Is a centeral Section of the same, with the Eye of Providence seated in the Center, as in the virtual Agent of Creation. Plate XXVI. Represents a Creation of a double Construction, where a superior Order of Bodies C, may be imagined to be circumscribed by the former one A, as possessing a more eminent Seat, and nearer the supream Presence, and consequently of a more perfect Nature. Lastly, Plate XXVII. Represents such a Section, and Segments of the same, as I hope will give you a perfect Idea of what I mean by such a Theory. *Fig.* 1. is a corresponding Section of the Part at A, in *Fig.* 2. whose versed Sine is equal to half the Thickness of the starry Vortice AC, or BA. Now I say, by supposing the Thickness of this Shell, 1. you may imagine the middle Semi-Chord AD, or AE, to be nearly 6; and consequently, thus in a like regular Distribution of the Stars, there must of course be at least three Times as many to be seen in this Direction of the Sine, or Semi-chord AE, itself, than in that of the semi-versed Sine AC, or where near the Direction of the Radius of the space G. Q.E.D.

"But we are not confined by this Theory to this Form only, there may be various Systems of Stars, as well as Planets, and differing probably as much in their Order and Distribution as the Zones of *Jupiter* do from the Rings of *Saturn*, it is not at all necessary, that every collective Body of Stars should move in the same Direction, or after the same Model of Motion, but may as reasonably be supposed as much to vary, as we find our Planets and Comets do.

"Hence we may imagine some Creations of Stars may move in the Direction of perfect Spheres, all variously inclined, direct and retrograde; others again, as the primary Planets do, in a general Zone or Zodiac, or more properly in the manner of *Saturn's* Rings, nay, perhaps Ring within Ring, to a third or fourth Order, as shown in *Plate* XXVIII. nothing being more evident, than that if all the Stars we see moved in one vast Ring, like those of *Saturn*, round any central Body, or Point, the general Phænomena of our Stars would be solved by it; see *Plate* XXIX. *Fig.* 1. and 2. the one representing a full Plane of these Motions, the other a Profile of them, and a visible Creation at B and C, the central Body A, being supposed as *incognitum*, without the finite View; not only the Phænomena of the *Milky Way* may be thus accounted for, but also all the cloudy Spots, and irregular Distribution of them; and I cannot help being of Opinion, that could we view *Saturn* thro' a Telescope capable of it, we should find his Rings no other than an infinite Number of lesser Planets, inferior to those we call his Satellites: What inclines me to believe it, is this, this Ring, or Collection of small Bodies, appears to be sometimes very excentric, that is, more distant from *Saturn's* Body on one Side than on the other, and as visibly leaving a larger Space between the Body and the

Ring; which would hardly be the Case, if the Ring, or Rings, were connected, or solid, since we have good Reason to suppose, it would be equally attracted on all Sides by the Body of *Saturn*, and by that means preserve everywhere an equal Distance from him; but if they are really little Planets, it is clearly demonstrable from our own in like Cases, that there may be frequently more of them on one Side, than on the other, and but very rarely, if ever, an equal Distribution of them all round the *Saturnian* Globe.

"How much a Confirmation of this is to be wished, your own Curiosity may make you judge, and here I leave it for the Opticians to determine. I shall content myself with observing that Nature never leaves us without a sufficient Guide to conduct us through all the necessary Paths of Knowledge; and it is far from absurd to suppose Providence may have every where throughout the whole Universe, interspersed Modules of every Creation, as our Divines tell us, Man is the Image of God himself.

"Thus, Sir, you have had my full Opinion, without the least Reserve, concerning the visible Creation, considered as Part of the finite Universe; how far I have succeeded in my designed Solution of the *Via Lactea*, upon which the Theory of the Whole is formed, is a Thing will hardly be known in the present Century, as in all probability it may require some Ages of Observation to discover the Truth of it."

The eighth and ninth letters, which are on the modes of conceiving space and time, and contain general reflections on the whole scheme, contain nothing which need be quoted. Wright seems to have been the first who started the idea of representing the solar system by selected objects on the earth. Representing the sun by the dome of St. Paul's, a sphere of eighteen inches diameter at Marylebone will be the earth, and so on. There is internal evidence that these letters were written in London.

I should sum up by saying that Wright appears to have been a man of great ingenuity, and of moderate learning, of a strong turn for the invention of hypothesis, and great power of appreciating its probability. He had a firm persuasion that astronomical discovery was then very imperfect, both in quantity and quality, a persuasion which regulated even his ordinary expressions. It is not often, in his day, that we find, as in his works, the planets described as the *known planets*, implying an assumption that there might be more. He gave the theory of the milky way which is now considered as established, contended for what is now called the central sun, inclining strongly to the belief of an actual central body, though he sometimes qualifies it by stating the alternative of a central body or a central point. He contends for the probability of different creations of the kind of which the milky way is one; but he does not seem to have known of more than half a dozen nebulæ, and he does not push his views so far as to conjecture that these "cloudy spots" are themselves other such creations: he rather refers them to condensations occurring in the mass of stars to which our sun belongs. His prediction of the ultimate resolution of Saturn's rings into congeries of small satellites remains to be verified; but it is thought by some to be most probable that such is the truth. It is hardly necessary to say that Wright supposes mutual gravitation to be the connecting agent between star and star, as well as between stars and their planets.

Kant adds to what he probably learnt from the review of Wright, the distinct supposition that the nebulæ are other specimens of constellative systems, and that these systems, with our own, may be but parts of a larger one, and so on. He also declares for Sirius as the central body of our system. Wright considers Sirius merely as our nearest neighbour.

There is an account of Thomas Wright (with a good portrait) in the Gentleman's Magazine for 1793, vol. lxiii. pp. 9, 126, 213. He was born at Byer's Green, about six miles from the city of Durham, September 22, 1711, the son of a carpenter, a small landholder. He was apprenticed to a clock-maker, then went to sea, and afterwards struggled for many years as a maker of almanacks, a lecturer, and a teacher of mathematics. During this time he published some works. At last he seems to have risen into note as a teacher of the sciences in noble families; and we find him in affluence towards the end of his life, but how it came is not stated. He built himself a handsome house at Byer's Green in 1756-62, and died there February 25,

1786. By various communications made by him to the Gentleman's Magazine from 1744 upwards, it appears that he was an observer, particularly of comets, a calculator of their elements, etc. In his younger days he was employed by Heath and Sisson as a maker of mathematical instruments; and he wrote on navigation and taught it with a reputation which procured him, in 1742, an offer of the professorship of navigation in the Imperial Academy of St. Petersburg. He was moreover an engraver, and even executed the plates for some of his own works; and as the one which I have described has so many quarto plates, effectively done in mezzotinto, and without the name of any engraver attached, I conclude, in spite of "by the best masters" in the title-page, they are of Wright's own workmanship. He had some acquired scholarship, but not of a very profound cast.

I learn from Professor Chevallier, of the University of Durham, to whom I am indebted for the references to the Gentleman's Magazine, that when the library of Mr. Allan of Darlington, the author of the memoir cited, was sold by auction in London in 1822, it contained, as the memoir states, the original copper of several of Wright's plates. And further, that Wright appears to have been consulted on matters of taste: for that in the chapter library of Durham there is a design by him for some alterations in the Cathedral, including an ornamented battlement with finials upon the western towers; which design was carried into execution, as is to be seen.

The works by Wright which are mentioned in the memoir, are some calculations of eclipses (single leaves, I suppose, descriptive of the phases, after the manner of the time); the *Pannauticon*, a work on navigation, published in 1734; *Louthiana*, a work on the antiquities of Ireland, of which one volume only was published in 1748; the treatise described in this article; and others which I do not note, as according to a common fashion of biographical memoirs, there is a confusion between works "completed" and works printed and published. Lalande mentions The Use of the Globes, London, 1740, 8vo; *Clavis Cœlestis*, being the explication of a diagram entitled A Synopsis of the Universe . . . London, 1742, 4to; and the work above described.

It seems to me that Wright is entitled to have his speculations considered, not as the accident of a mind which must give the rein to imagination, and sometimes get into a right path, but as the justifiable research and successful conclusion of thought founded on both knowledge and observation. And I submit that his name ought to be enrolled in the list of discoverers.

University College,
March 7, 1848.

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